HOW BACTERIA CONTROL YOUR MIND

HOW IT WORKS

SCIENCE | OLOGY | TRANSPORT | HISTORY | SPACE

OLYMPIC GAMES SCIENCE

HOW YOUR BRAIN WORKS

PEREGRINE FALCON
The deadly tactics of this bird of prey revealed

KNOW YOUR HAMMERS
Nail the different designs & their many uses

THE ICE AGE
Mammoths, sabre-toothed tigers & giant sloths

933 FACTS AND ANSWERS INSIDE

BECOME A TOP GUN

FROM COCKPIT LAYOUT TO COMBAT MANOEUVRES
DISCOVER WHAT IT TAKES TO FLY A FIGHTER JET

PARALLEL UNIVERSES
Is our universe just one of many?

+ LEARN ABOUT

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WELCOME
The magazine that feeds minds!

"More than 10,000 athletes will compete for 306 gold medals across 42 Olympic sports"
Olympic Games Science, page 22

Meet the team…

Dave
Editor-in-Chief
It's nearly Air Festival time and while awaiting the return of the Red Arrows and the Eurofighter Typhoon, I enjoyed reading about fighter jets.

Jackie
Deputy Editor
Our bodies are made of a one-to-one ratio of human to bacterial cells. So I guess you could say we are living in a microbial world and I am a microbial girl.

Katy
Research Editor
You might want to sit down before you delve into our multiverse feature – the idea of infinite parallel universes is enough to make anyone feel dizzy!

Duncan
Senior Art Editor
It's the Rio Olympics this summer, and in this issue we're discus-ing how Olympians set those world records (I'm taking notes for the new hockey season).

Briony
Assistant Designer
Finding out how airport baggage scanners and rebreathers work has got me in the holiday mood. Next issue will be designed poolside!

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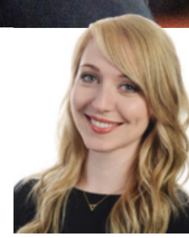

Can you believe it's been 30 years since Tom Cruise entered the Danger Zone? Naturally, this made us feel the need, the need for speed, so in honour of this monumental movie we found out what it takes to fly one of the most complex military machines in the world – the fighter jet.

Speaking of speed and stamina, it's time for the world's greatest sports stars to take their marks as the Olympic Games begin. In true **How It Works** style, we take a look at the science and technology behind some of the most popular events, and the ruthless training schedules that prepare them for a place on the podium.

And as this issue hits the shelves, the fifth *Ice Age* film will be unleashed in cinemas. We reveal the true beasts of frozen Earth, and the causes behind these extreme glacial periods that once transformed our planet into a giant snowball! You'll also discover why our universe could be one of many, how bacteria control your mind and much, much more. Enjoy this jam-packed issue!

Jodie
Jodie Tyley
Editor

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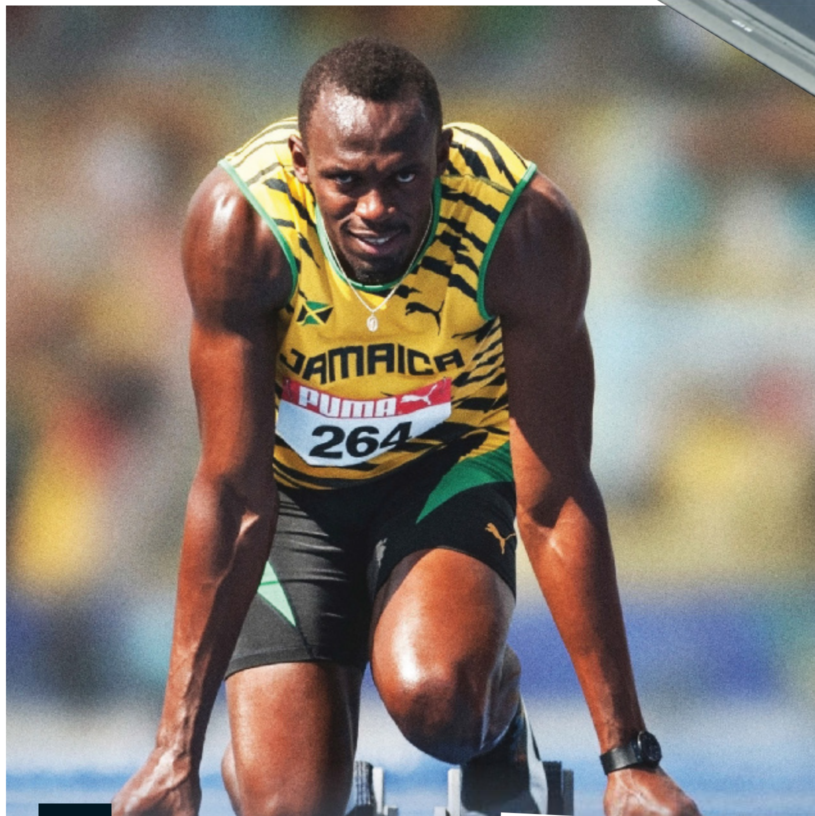


22 **OLYMPIC GAMES SCIENCE**

34 **Engineering the tallest bridge in the world**

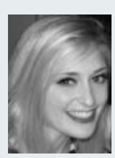
74 **Parallel universes**

Meet the experts…

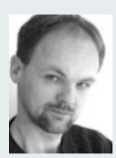
Laura Mears
It may be summer, but Laura looks back to a time when Earth was smothered in ice. You'll discover what triggers eternal winter, the ferocious beasts that roamed the frozen landscape, and why humans outlived them.

Michael Haskew
As the author of several military books, including *The Sniper At War* and *Order Of Battle*, military expert Michael reveals what it takes to fly a fighter jet this issue.

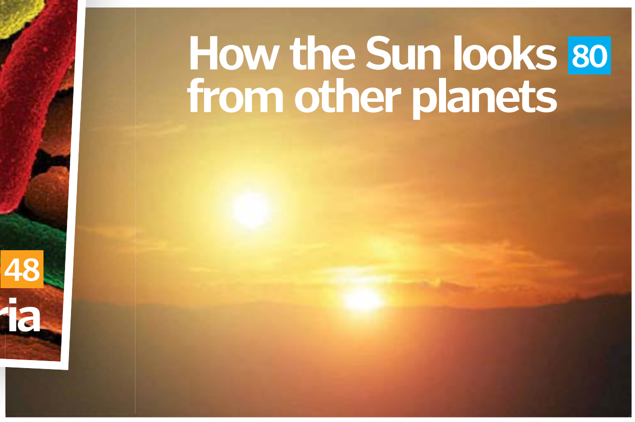
Jonny O'Callaghan
Our universe may be one of many, physicists say. *IFL Science* reporter Jonny explains why we could live in a multiverse and examines what this could mean for humanity.

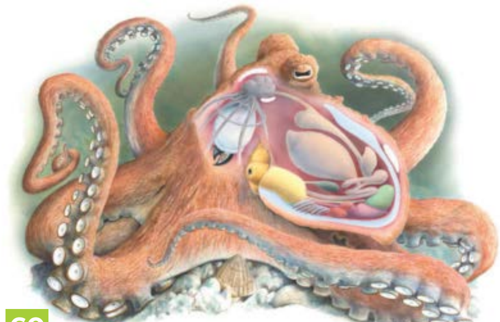


Ella Carter
This issue, Ella takes us to China's incredible rainbow mountains, dives into the sea to explain octopus anatomy, and looks skyward at the world's fastest bird.



Luis Villazon
It's time for the Olympic Games to begin and Luis is on-hand to reveal the amazing science and tech behind record-breaking super humans over on page 22.





REGULARS

HOW BACTERIA CONTROL YOUR MIND
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PARALLEL UNIVERSES

Scanning the pyramids

How cosmic rays and drones are helping to solve the mysteries of Ancient Egypt

The giant pyramids of Egypt hold many secrets. To this day, no one quite knows how the Egyptians built these enormous structures before the advent of heavy machinery, and it is believed that many could contain secret chambers, hidden to protect the remains of pharaohs lying inside. To uncover these mysteries and more, ScanPyramids – a project set up by Cairo University and the French HIP (Heritage, Innovation and Preservation) Institute – is using innovative technologies to look inside four of Egypt's largest pyramids, without causing any damage to the structures.

First, they use cameras equipped with sensors to measure the infrared waves emitted by the pyramids. This allows them to locate any cold air currents on the structures' surfaces, which could reveal draughty cavities, rooms or hallways lying inside. Then, to create images of the internal structures, muon radiography is used, a technique that has been successfully implemented to study volcanoes and the Fukushima nuclear reactors.

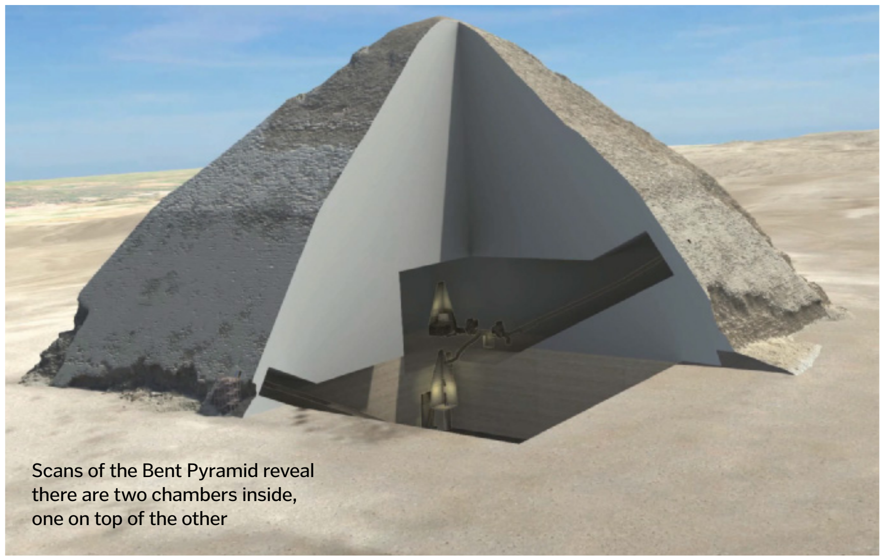
Finally, cameras attached to drones capture images of the pyramids from all angles, allowing for the creation of detailed 3D reconstructions of their exteriors. One structure, the 105-metre tall Bent Pyramid, has been scanned so far, already disproving the long-held theory that Pharaoh Sneferu's tomb is hidden inside.

Collecting muons

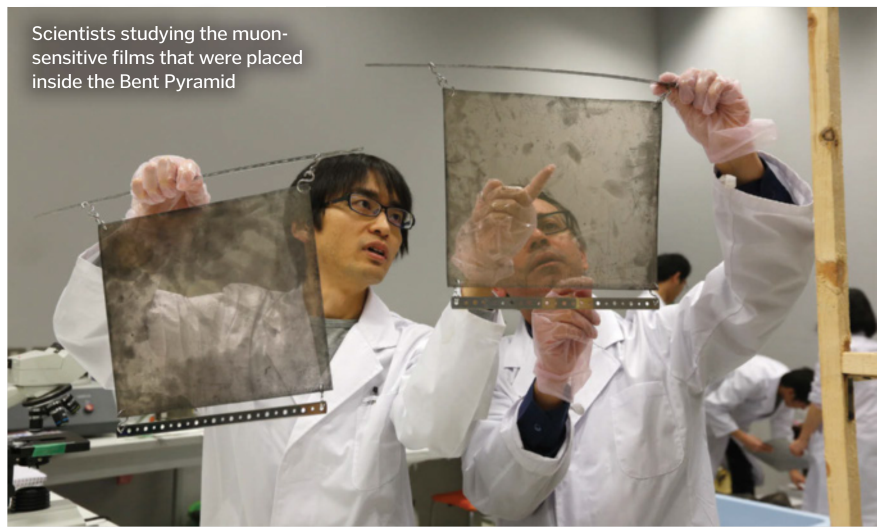
Muon-detecting plates being set up in the lower chamber of the Bent Pyramid

Muons are particles that are created when cosmic rays collide with atoms in the Earth's atmosphere. They are constantly raining down on us at the speed of light, and are able to pass through any structure. By installing plates covered with muon-sensitive film inside the lower chamber of the pyramid, the ScanPyramids team were able to study the accumulation of muons passing through the structure over time. This enabled them to discern the location of empty chambers, which the muons passed through easily, and the denser walls, which deflected and absorbed some of the particles.

The Bent Pyramid was the first to be built with smooth, rather than stepped, sides

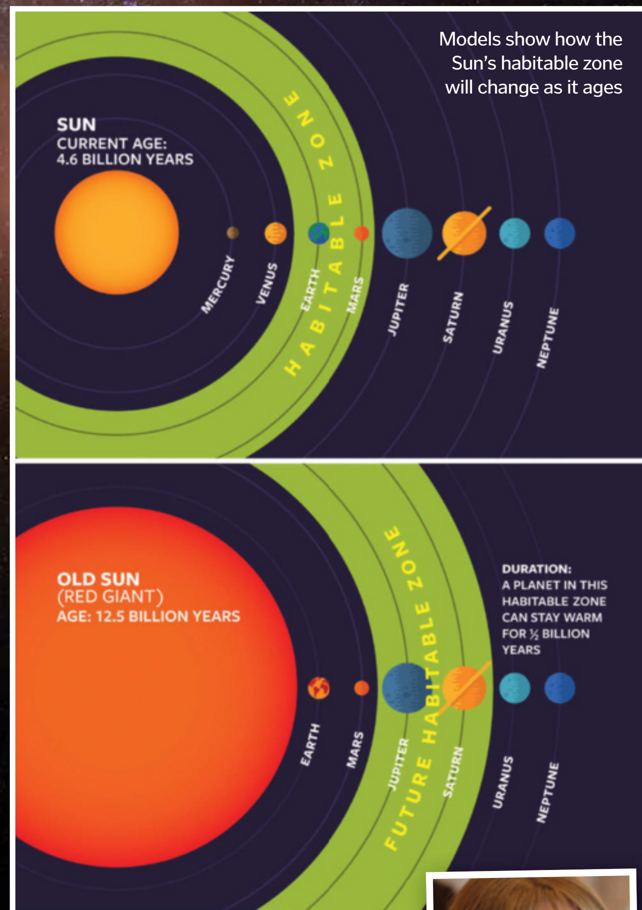


Scans of the Bent Pyramid reveal there are two chambers inside, one on top of the other



Scientists studying the muon-sensitive films that were placed inside the Bent Pyramid

If the Sun becomes a red giant, the ice on Jupiter will melt



Models show how the Sun's habitable zone will change as it ages

TALKING POINT

IS ALIEN LIFE OUT THERE?

We ponder where life could be hiding in the universe

Throughout the universe there are at least 100 billion potentially habitable worlds, yet so far we only know of one with the conditions for life to thrive. The reason life can exist on Earth is because it lies within a habitable zone, also known as the 'Goldilocks Zone' – a theoretical region around a star where any planets or moons are at the perfect distance for liquid water to be stable on their surface.

Earth has been sitting in its habitable zone for about 4.5 billion years, but in another few billion, the Sun will expand to become a red giant, moving the habitable zone outwards and turning Earth and Mars into hot wastelands. As a result, the moons of Saturn and Jupiter will then become warm enough for any ice on their surfaces to melt.

By modelling this scenario, astronomers at the Carl Sagan Institute have worked out that planets can remain in a red giant's habitable zone for up to 0.5 billion years – long enough for life to flourish – making them viable candidates for alien life, now or in the future. We spoke to astrobiologist, planetary geologist and author Louisa Preston, whose latest book explores this intriguing topic.

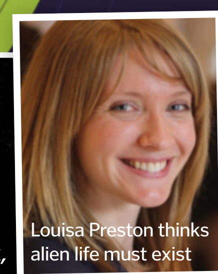
What do you think are the chances that life exists elsewhere in the universe?

I think life must exist elsewhere in the universe. The conditions that existed on Earth around the time life first appeared are not unique to us. We are finding other rocky worlds with forms of water on them, as well as worlds orbiting at the right distance from their sun to theoretically support liquid water and an atmosphere.

Carbon is also the third most abundant element in the universe found within cosmic dust, asteroids and comets that have rained down on every planetary body in the Solar System. Surely somewhere else these ingredients for life came together and made an organism. Whether this life had the right environment to support it into becoming an intelligent being just like ourselves, who knows?

Where are astrobiologists currently searching for alien life?

In our Solar System we are using Earth-based telescopes, space-based satellites and orbiters, and of course the famous rovers, to search planets such as Mars and the icy moons of Jupiter and Saturn such as Europa, Enceladus and Titan, for signatures of life. Outside our local neighbourhood we are also starting to look at exoplanets and their atmospheres, hunting for hints of a life-friendly environment such as the presence of oxygen, ozone, water and methane.



Louisa Preston thinks alien life must exist

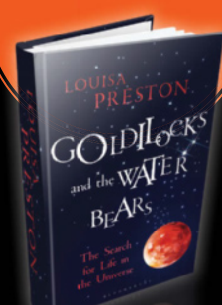
If we do find alien life, what do you think it will look like?

Although I would love for it to look like a three-eyed bat, flying whale or even the stereotypical grey/green human-esque model used in science fiction films, it is much more likely to be a simple life form similar to a bacterium and to be honest even this is quite unlikely. The first evidence we uncover that hints at life will probably be a carbon-based molecule created by life such as a protein or fatty acid. Admittedly not as visually stimulating, but for us it will be equally as exciting.

Do you think we should be wary about attempting to make contact with extraterrestrial life?

The chances are they will be more advanced than us and who knows whether they will want to speak to us or see us worthy of contact, but I don't feel that should stop us from trying.

Goldilocks And The Water Bears by Louisa Preston is out now



NEWS BY NUMBERS

1,284

New planets discovered by NASA's Kepler space telescope announced in May

390,900

Estimated number of plant species known to science

120m

Estimated maximum height of ancient tsunamis on Mars

>100

Deliveries made by DHL's delivery drone so far

186

The number of days astronaut Tim Peake spent on board the ISS

"The sled levitated above the track using magnets"

Hyperloop hopes to be transporting cargo by 2019 and people by 2021

High-speed Hyperloop

Early tests of Elon Musk's transport concept reach 187km/h

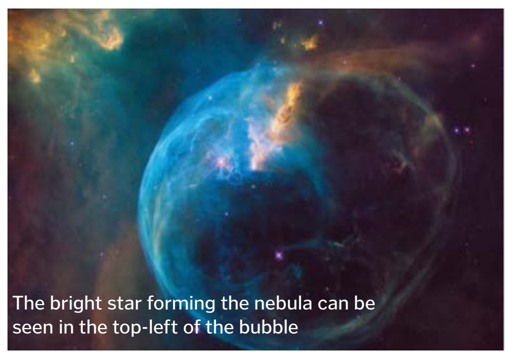
The public have had their first glimpse of what could be the future of transport – the hovering Hyperloop. Tesla co-founder Elon Musk first pitched the idea of a transport system that would send people and cargo through tubes at the speed of sound back in 2013. Now the first tests of his vision have been carried out in the Nevada desert, with a metal sled accelerating to 187 kilometres per hour in just 1.1 seconds. The sled levitated above the track using magnets, reducing friction so that it could reach high speeds.

Grow a second skin

Scientists have developed a new material that can smooth wrinkles

As skin ages, it loses its elasticity, but now scientists at Massachusetts Institute of Technology have found a way to restore its healthy, youthful properties. Their 'second skin' is applied in a two-step process. First, a cream containing a silicon-based polymer is rubbed onto the skin, then a second cream acts as a catalyst to form a strong, transparent, flexible film that protects and tightens the skin. With further development, the team hope that it can also be used to deliver drugs and treat skin conditions such as eczema.

The second skin is invisible and lasts for up to 24 hours



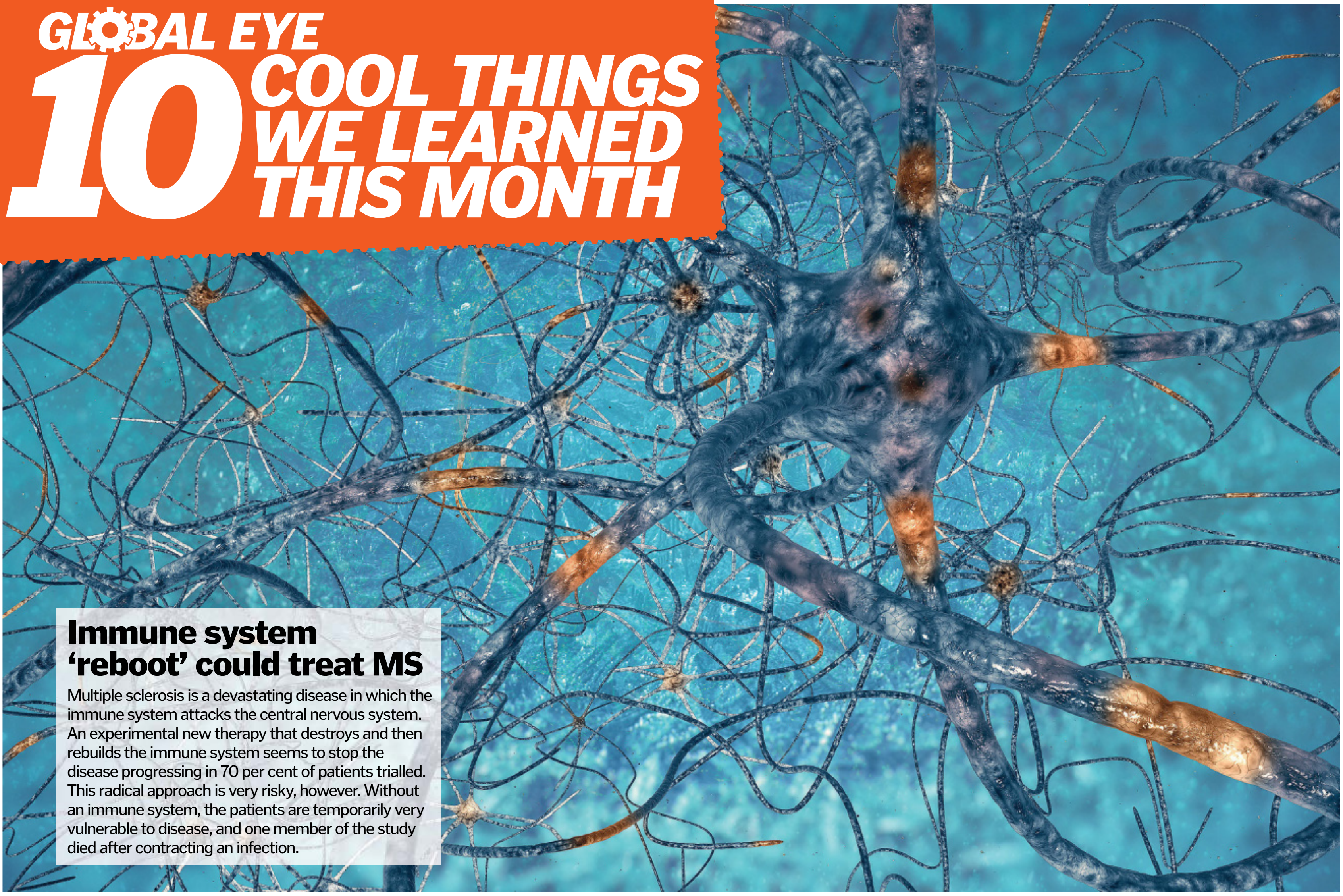
The bright star forming the nebula can be seen in the top-left of the bubble

Hubble spies a bubble

Telescope captures image of the Bubble Nebula for its 26th birthday

7,100 light years from Earth, in the constellation Cassiopeia, a star 45 times more massive than our Sun has been captured forming the Bubble Nebula. Gas from the star gets so hot that it escapes into space as a stellar wind, blowing at over 6 million kilometres per hour. This wind sweeps up the cold, interstellar gas in front of it, forming a bubble. The oxygen within the bubble is hot enough to emit a blue light, while the cooler hydrogen and nitrogen appear yellow.

10 COOL THINGS WE LEARNED THIS MONTH



Immune system 'reboot' could treat MS

Multiple sclerosis is a devastating disease in which the immune system attacks the central nervous system. An experimental new therapy that destroys and then rebuilds the immune system seems to stop the disease progressing in 70 per cent of patients trialled. This radical approach is very risky, however. Without an immune system, the patients are temporarily very vulnerable to disease, and one member of the study died after contracting an infection.

Cats understand cause and effect

Cats seem to use basic physics principles in order to predict where possible prey hides. Researchers from Japan placed objects in containers, which would rattle when shaken. The cats focused more on the containers that rattled, showing that they anticipate the existence of objects they can't see based on what they hear.

Dancing together helps us bond

Anthropologists from the University of Oxford have found that children who dance together connect to those who move in time with them. Groups of children were taught simple routines, and performed them facing one another while wearing headphones. Questionnaires taken before and after revealed that the children felt closer to those who danced like them, compared to those performing other moves.

Tutankhamun's dagger was made from a meteorite

Analysis of a knife buried alongside the teenage pharaoh has revealed that it is likely to contain extraterrestrial metals. The blade was examined by researchers using X-rays, and was found to contain high levels of nickel, which is characteristic of meteoritic iron. The dagger is very well made, suggesting that Egyptian ironworkers during Tutankhamun's rule were highly skilled.

Light pollution affects 99 per cent of Europeans

A new study has revealed that over 80 per cent of the world's population has light-polluted skies. Artificial lights brighten our surroundings so much that around 14 per cent of us don't use our dark-adapted vision when looking at the night sky.

NASA set fire to a spacecraft

"Don't start a fire" is practically Space Travel 101, but NASA's decision to deliberately set a Cygnus supply vehicle alight is an important experiment. Inside the spacecraft, the experiment enclosure (pictured) contained a burnable sample of cotton-fibreglass material, which was ignited by a hot wire. The results of the Spacecraft Fire Experiment (Saffire) will help scientists understand how fires spread in microgravity, which is vital for safety.

'Birdbrain' should be taken as a compliment

Avian intelligence has baffled scientists for many years now. How can such small brains be capable of complicated cognitive behaviour? Analysis of birds' brains may have the answer: a team of neuroscientists have revealed that birds' neurons are more densely packed. This means birds fit more brain cells into their tiny heads than the equivalent brain mass of mammals, even some of the smartest primates.

Air rage is caused by class

If you find yourself extra irritable on a flight, it might well be down to the presence of first-class seats. A study has shown that air rage incidents are nearly four times more likely to occur on planes with first-class cabins. Researchers think that having first-class seats makes economy passengers much more aware of inequality, which can make them angry.

Cold coffee beans make a better brew

Scientists have unlocked the surprisingly simple secret of how to make tastier coffee: using cold beans. Researchers from the University of Bath discovered that cooling the roasted coffee beans helped create finer and more uniform particles. These smaller particles release more flavour compounds when the grounds are brewed.

Bionic leaves can create fuel

Scientists from Harvard University have developed bionic leaves capable of artificial photosynthesis. While photosynthesis has previously been replicated in the lab, this new system is much more efficient than the natural process, and can create liquid fuels with the help of hydrogen-eating bacteria.

BECOME A TOP GUN

FROM COCKPIT LAYOUT TO COMBAT MANOEUVRES DISCOVER WHAT IT TAKES TO FLY A FIGHTER JET

The life of a fighter pilot requires courage, commitment and energy. While flying one of the most complex military machines in the world, monitoring and manipulating multiple systems, a pilot's training, intelligence and sharply honed skills work seamlessly. However, pilots never stop learning, growing and pushing themselves to the limit – both physically and mentally.

"Complete dedication is required outside the cockpit too," says US Navy Lieutenant Joshua S Bettis. "The choice to fly jets for the Navy is life-consuming. The jets are expensive and dangerous. So, when a pilot isn't actually flying he is practising flying or studying. The current ratio of maintenance hours per flight hour also means that many sailors spend long days preparing jets to fly for short periods. In a training environment, if a slip-up doesn't end in a mishap, it will affect a pilot's grades. There is seemingly an inexhaustible supply of young officers that would jump at the opportunity to take his spot."

Fighter pilot training is intense and ongoing. Young jet pilot candidates complete initial flight screening in propeller-driven aircraft such as the Cessna 172. US Navy pilots progress through primary and advanced flight training, familiarising themselves with additional aircraft such as the conventional Beechcraft T-34C Turbomentor and the McDonnell Douglas/ Boeing T-45C two-seat advanced jet trainer.

Fighter pilots complete up to three years of training before earning their wings. During that time they spend countless hours in the classroom, respond to emergency situations in the simulator and endure the centrifuge, which spins the pilot vigorously to replicate the intense G-forces they will encounter during the majority of in-flight manoeuvres.

"The training we receive is everything from basic airmanship to air-to-ground munitions delivery and air-to-air combat," explains Lieutenant Commander Josh Denning. "We also train to land on aircraft carriers and refuel in flight. Flying is hard work. It requires hours of preparation for each flight. A typical 1.5-hour flight would consist of approximately two hours of briefing before the flight, the flight itself, and then anywhere from one hour to many hours for a debrief of the event."

Navy fighter pilots are constantly reminded that the success of a mission depends on them. Once they've mastered a fighter capable of flashing into combat at more than 1,600 kilometres per hour, the fighter pilot must be ready to spring into action at a moment's notice.

FLIGHT GEAR

Fighter pilots require specialist equipment to tackle death-defying manoeuvres

Suiting up is a critical aspect of the job. Fighter pilots' equipment is often tailored to their mission, whether the jet aircraft is flying faster than the speed of sound, engaging hostile targets or the pilot is on the ground, evading capture or fighting for survival.

"A pilot wears a helmet and visor, a mask which is worn at all times with a radio incorporated, a flight suit made from aramid (Nomex) – a material that is not fireproof but will char instead of melt – gloves, steel-toed boots, a G-suit, harness and survival vest," explains Lieutenant Bettis. "Other types of equipment vary depending on your mission, whether it is peacetime training or combat."

The flight suit is ideal for protecting the fighter pilot in case of an onboard fire. "It's like zip-up pyjamas with a few pockets. It's pretty simple," Bettis describes. "The G-suit, on the other hand, is an expensive piece of gear that plugs into a receptacle in the cockpit." Heavy acceleration can generate high G-forces on the pilot, sending blood rushing towards their head or their feet. Either scenario can cause a pilot to pass out, so pressurised G-suits are worn to combat this.

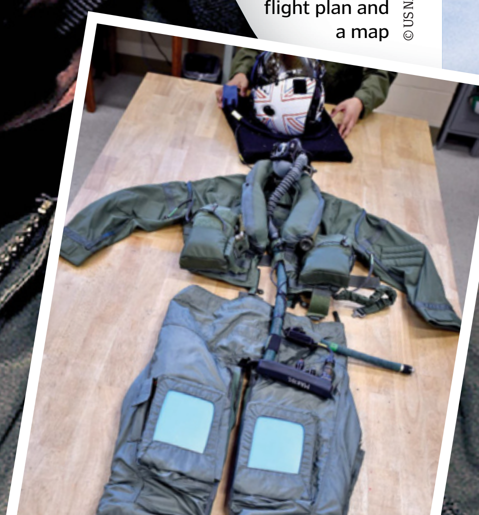
In cold weather, pilots don a rubber-lined exposure suit that functions much like a diver's wetsuit, providing insulation and retaining body warmth if they land in water after a forced ejection. Gloves are made of Nomex material similar to the flight suit, and are both fire-resistant and warm in cold weather.

"We carry a large assortment of mostly survival gear on our vest," explains Lieutenant Commander Denning, "in case we ever have to eject." The survival vest contains a hand-held GPS for orientation, waterproof matches, thimble-like lights that turn fingertips into miniature flashlights, camouflage paint, a tourniquet for wound treatment and more.

Every pilot's outfit is meticulously thought out for their safety

Next-gen helmets

What tech makes the F-35 Gen III a pilot's ultimate wingman?

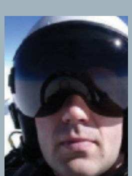


The flight suit's transparent thigh pockets usually hold the flight plan and a map

Meet the pilots

Lieutenant Joshua S Bettis, US Navy

Lieutenant Bettis graduated from the US Naval Academy in 2006 and was designated a student naval aviator. He earned his wings in 2009, subsequently serving with Squadron VFA-125 in Lemoore, California, flying the F/A-18C Hornet fighter. In 2011, he transitioned to the Civil Engineer Corps and currently serves with Naval Facilities Engineering Command in Washington, DC.



Lieutenant Commander Josh Denning, US Naval Reserve

Lieutenant Commander Josh Denning was commissioned in the US Navy through Officer Candidate School in 2007. He earned his wings in 2009, serving at naval air stations in Florida, Texas, and California. He flew the F/A-18E and F/A-18F Hornet fighters. He works as a police officer and as a reserve staff supply officer for the Seventh Fleet.

IN THE COCKPIT

The fighter pilot monitors and operates scores of switches, controls and buttons

During all phases of operation, pre-flight, in-flight, and post-flight, the fighter pilot is constantly aware of their surroundings, and the command centre of the jet aircraft is the cockpit. To those who have not trained as pilots, the confusing mass of control panels is overwhelming, but to seasoned professionals the operation of these instruments is second nature, thanks to years of training.

"Pilots develop a cockpit scan over time, where each instrument is monitored at an appropriate interval," relates Lieutenant Joshua Bettis. "The scan varies depending on the pilot's mission. Pilots also spend a significant amount of time in the books. They must know the proper use and limitations of every piece of gear on the jet."

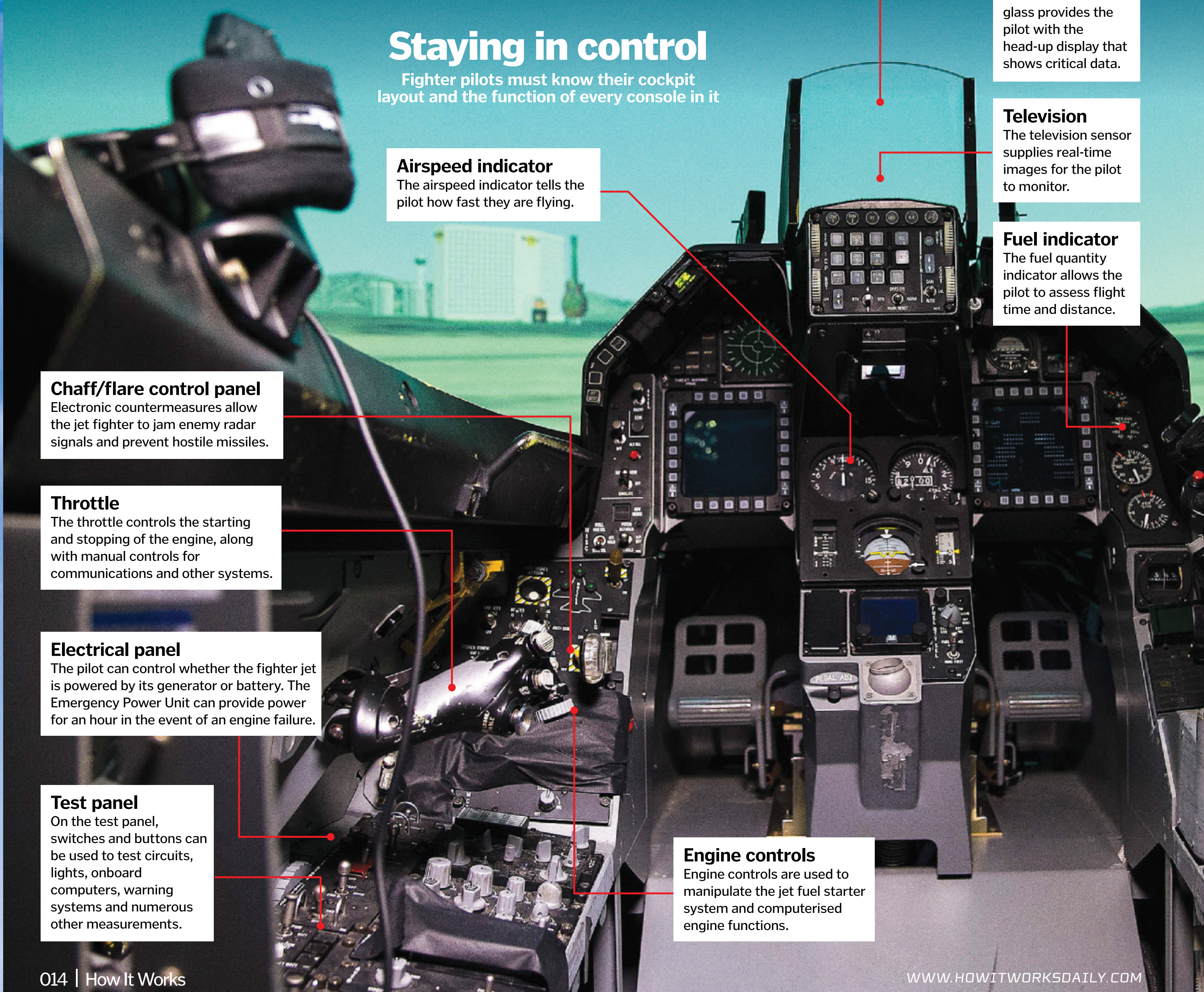
Today's fighter jets are configured for a variety of missions, engaging in air superiority operations and ground targeting. "Everything in the cockpit is as streamlined as possible for the pilot to operate the systems, their hands never leaving the controls," says Lieutenant Commander Josh Denning. "Before we even learn to fly airplanes we go through many hours of cockpit familiarisation, learning the systems and their respective controls in the cockpit."

The pilot has to know their stuff when a split second could be the difference between being the hunter or the hunted. "Training depends on the complexity of the gear the pilot is learning," Bettis continues. "Ground school covers complex instrument function and theory, followed by simulators with seasoned instructor pilots. Next, the instruments are utilised in manoeuvres and tactics in the aircraft – normally in a 'demo-do' format, where the instructor demonstrates proper usage before the student makes an attempt."

Scores of knobs, buttons and switches govern the function of at least 20 systems, each of them

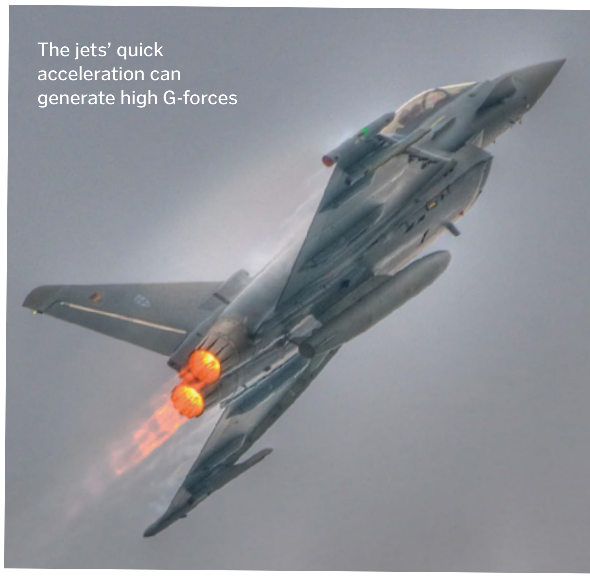
Staying in control

Fighter pilots must know their cockpit layout and the function of every console in it



critical to the fighter's performance and the survival of the pilot. These include the engine along with other systems related to fuel, environment and temperature, electrical systems, flight control, hydraulics, landing gear, autopilot, lighting, communications, navigation, IFF (Identification, Friend or Foe), weapons, radar and more.

"As pilots progress in their careers and aircraft get more expensive to fly, the learning curve gets steeper," explains Lieutenant Bettis. "Students work through 20 or more flights in primary flight training just to be able to solo a T-34C. Conversely, a newly winged aviator that is transitioning into the Hornet is expected to solo on his third or fourth flight. Simulators are an excellent tool used to teach pilots and evaluate their performance in a low risk setting. They allow instructors to create emergency situations that otherwise wouldn't be feasible, and adjust conditions such as weather to challenge a pilot that is working on instrument flight."


The jets' quick acceleration can generate high G-forces


Mastering the cockpit controls of a fighter jet takes years of training

"A split second could be the difference between being the hunter or the hunted"

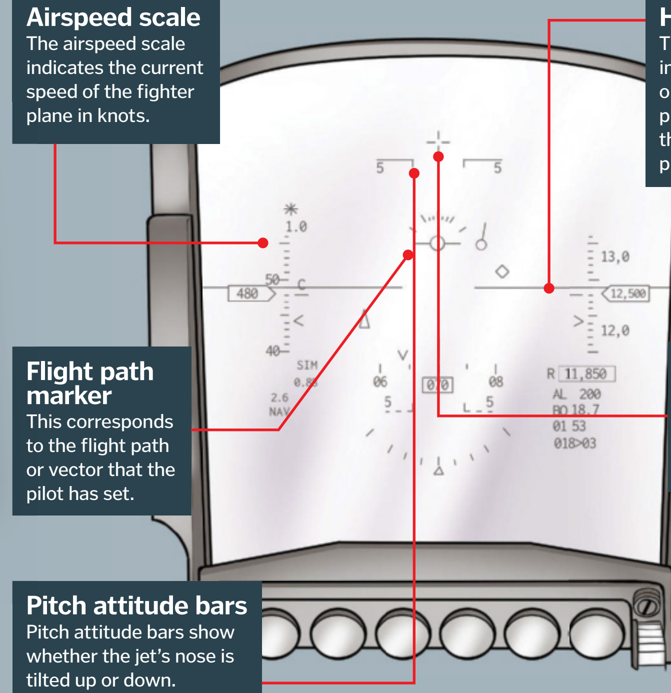

The F-35B is specially designed to take off over short distances

Nuclear consent switch
If nuclear weapons are carried, manipulating this switch gives the jet consent to arm and release them.

All good in the HUD

The head-up display shows pilots their essential real-time data

The fighter jet head-up display (HUD) presents data to the pilot in their forward field of view through the integration of three basic components: the projector unit, combiner and video generation computer. This setup means they don't have to divert their eyes while in flight, which minimises the distractions of looking down or away from the front of the aircraft, and avoids the pilot having to refocus their eyesight when assessing data. A typical HUD provides the airspeed, altitude, horizon line and global positioning, as well as navigational and aerial combat information. This includes data such as angle of attack, number of available weapons, range to target and whether or not they are locked onto an enemy aircraft.



Airspeed scale
The airspeed scale indicates the current speed of the fighter plane in knots.

Horizon line
The horizon line indicates the orientation of the plane with respect to the horizon in the pilot's line of sight.

Flight path marker
This corresponds to the flight path or vector that the pilot has set.

Gun cross
The gun cross shows where the nose of the aircraft is pointing.

Pitch attitude bars
Pitch attitude bars show whether the jet's nose is tilted up or down.

An F-35B undertakes one of its many test flights before being assigned to a fleet

F-35 jets have clocked up a total of 60,000 flight hours since 2006

Pilots flying the F-35 have a 360-degree view of their surroundings

Pilots can communicate securely with commanders on the ground

Huge tanker aircraft can refuel fighter jets in mid-air

Two F-35C Lightning II jets (foreground) fly alongside two F/A-18 Super Hornets

© WIKI; Lockheed Martin

IN FLIGHT

With great power comes great responsibility: how to handle a fighter jet like a pro

Few fighter pilots would deny that the adrenaline rush of take-off, flight and landing is exhilarating, but they are also clear that the experience comes with significant responsibility. "Inside the cockpit there can be no complacency," warns Lieutenant Bettis. "Even the greatest pilots are one mistake away from demonstrating their mortality."

The fighter jet is designed for speed and manoeuvrability, and pilots feel they are on the aircraft rather than inside it, surrounded by the cockpit. "You literally strap the plane on to you," says David Collette, a former F-16 pilot in the US Air Force. "The plane is your life, but you are the brain."

The F-22 Raptor can cruise at supersonic speeds

In contrast to the wrangling of a fighter jet, commercial aircraft are designed for stability, a smooth ride and passenger comfort. In a fighter jet there are no passengers, just highly skilled professionals who are trained to complete dangerous missions. The fighter jet accelerates like a race car, and the characteristics of the aircraft shape and mould the flight experience. The shake of turbulence is never cushioned.

"Flying a fighter is the most exhilarating feeling I have ever had," explains Lieutenant Commander Denning. "There is an absolute sense of freedom while flying, especially in a high performance airplane such as the Hornet. G-forces feel as if you have weight pressing down on every part of your body. It takes a lot of practice to master the physiology of fighting the forces you experience in the cockpit to maintain consciousness and continue your mission. It is a very intense workout, and sweating out as much as five pounds [2.3 kilograms] of body weight is not uncommon under our most physically stressful missions."

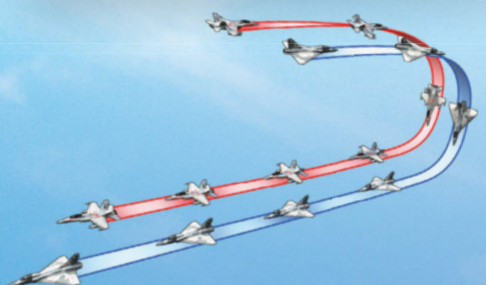
The force is strong

Tight turns, steep dives and swift climbs are all in a day's work for the fighter pilot, and the laws of physics take their toll. The power of gravity exerted on the human body during acceleration, deceleration and turning is known as G-force (G). Standing still you experience 1G under gravitational pressure, but when flying the Gs that pilots feel are directly proportional to the jet's changing velocity. Ordinary activities like riding a roller coaster, or heavily accelerating or braking in a car, could generate up to 3Gs. Fighter pilots, flying at tremendous speeds may 'pull' up to 9Gs, restricting the normal flow of blood and potentially causing a blackout. During manoeuvres the pilot is at great risk when blood pools in the lower extremities and the brain is starved of oxygen. To ward off the effects of G-forces, pilots wear a G-suit that provides a continuous flow of air, operating like a large blood pressure cuff.

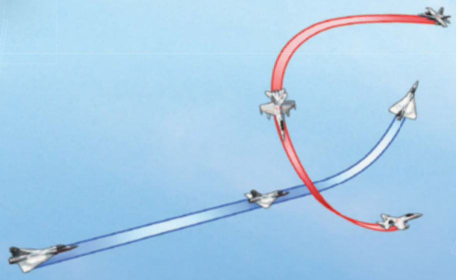
A US Marine Corps fighter pilot dons gear, including the G-suit, prior to a mission

Aerial combat manoeuvres

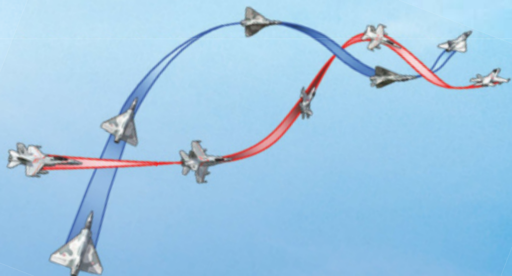
Fighter pilots execute precise moves to gain the decisive edge on an adversary



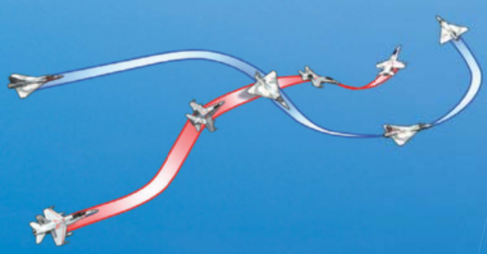
Turning in
A pilot seeking the most advantageous firing position on the tail of their adversary may execute this turn to close in.



Lead turn
This move enables a pursuing fighter pilot to close in on their opponent by starting to turn before the planes pass each other.

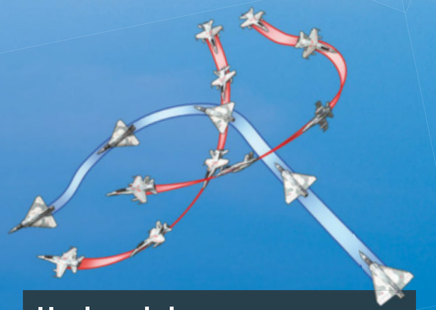


Rolling scissors
Often following a high-speed overshoot, an evader reverses into a vertical climb and barrel roll, compelling the pursuer to follow.



Flat scissors
This manoeuvre involves two planes weaving from side to side as they each try to get behind the other.

Bracket
Two pursuers launching a pincer attack force the evader to choose which opponent they will engage.



Hook-and-drag
Two persuers launching a pincer attack can take advantage of an evader's turn towards either of them.


Ejecting is always a last resort for fighter pilots

SAFETY FIRST

Fighter pilots must be vigilant at all times

The warning light flashes. Sights, sounds and sensors alert of potential disaster. Instinctively, the pilot takes action, as safety is second nature. Then, the exercise is over. The flight simulator has done its job so the pilot will know how to do theirs. "The simulators are run by former pilots with a breadth and depth of experience," remarks Lieutenant Bettis. "However, nothing replaces seat time in the jet."

During that "seat time" the pilot is constantly alert, blending their knowledge with onboard systems that keep both pilot and plane safe. Flying is a risky business. Not only does the pilot's life depend on it, the fate of a jet aircraft worth millions is also in their hands.

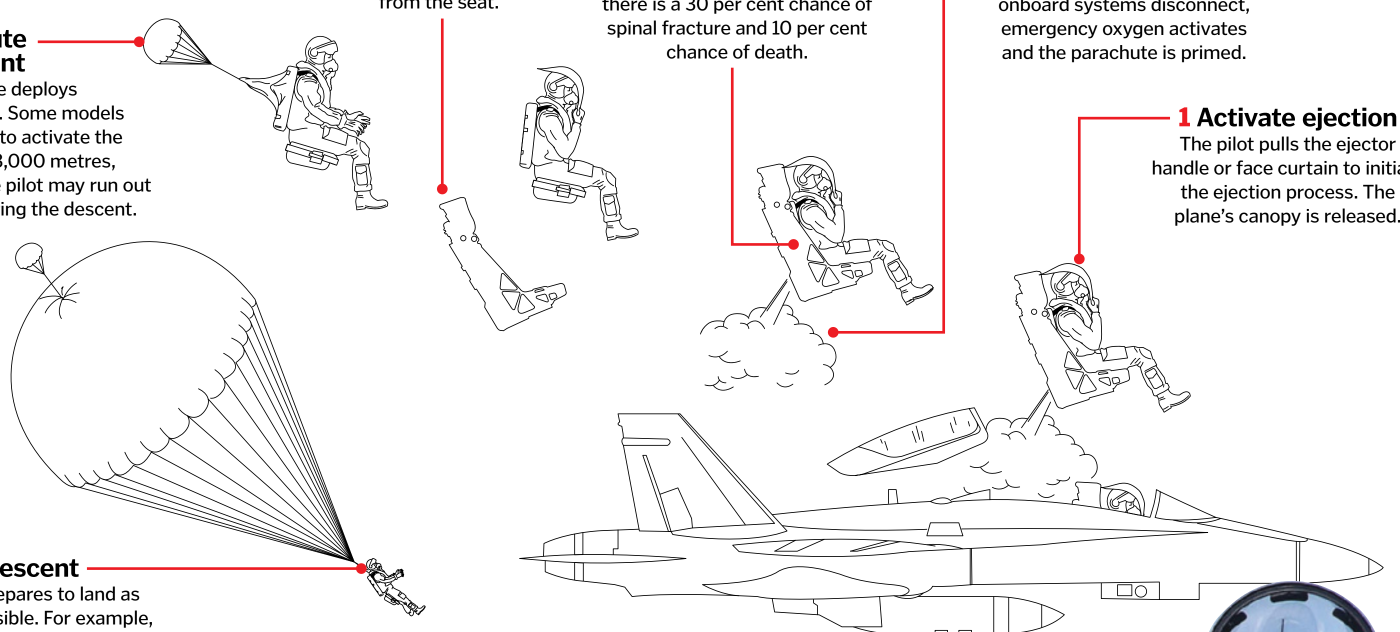
"Flying an airplane like the Hornet demands 100 per cent of your focus and situational awareness for 100 per cent of the time," relates Lieutenant Commander Denning. "Flying is terribly unforgiving for any carelessness, incapacity or neglect. There are systems in the airplane that alert us to several different types of emergencies, but most importantly it's the focus you must maintain that keeps a pilot safe."

Safety begins with pilot awareness and follows established procedures. From suiting up with indispensable gear to a huge range of pre-flight checks, the pilot works to minimise risk, through take-off, mission fulfilment and landing.

"Flying a fighter is the most exhilarating feeling I have ever had" – Lieutenant Commander Denning

The last resort

Pilots only eject from their jets when all other options are exhausted



1 Activate ejection
The pilot pulls the ejector handle or face curtain to initiate the ejection process. The plane's canopy is released.

2 Rockets fire
The ejection rocket ignites as the seat zips up guide rails, onboard systems disconnect, emergency oxygen activates and the parachute is primed.

3 Acceleration
Seat and pilot are shot upwards, to around 60 metres above the plane. The intense force means there is a 30 per cent chance of spinal fracture and 10 per cent chance of death.

4 Clearing
One second after the ejection, the pilot – along with their survival gear – is released from the seat.

5 Parachute deployment
The parachute deploys automatically. Some models have sensors to activate the chute below 3,000 metres, otherwise the pilot may run out of oxygen during the descent.

6 Descent
The pilot prepares to land as safely as possible. For example, if they are over water, they can deploy a life raft.

Man versus machine

Military applications of drones are revolutionising the future of the fighter pilot. The virtually silent, sophisticated drone removes the risk to human life, and executes its lethal task with pinpoint accuracy. However, the human element may never completely disappear from the sphere of aerial combat.

"Manned combat aircraft will be around for the foreseeable future," asserts Lieutenant Commander Denning. "Today's unmanned aircraft mainly focus on intelligence and surveillance missions with the capability to launch some limited air-to-ground missions, but as far as fighter aircraft are concerned, there are no limits."

While engineers may one day remove the fighter pilot from the cockpit, a new breed of expert fliers will remain, stationed at remote locations on the ground, handling the drone, watching and waiting, locking onto targets and firing.

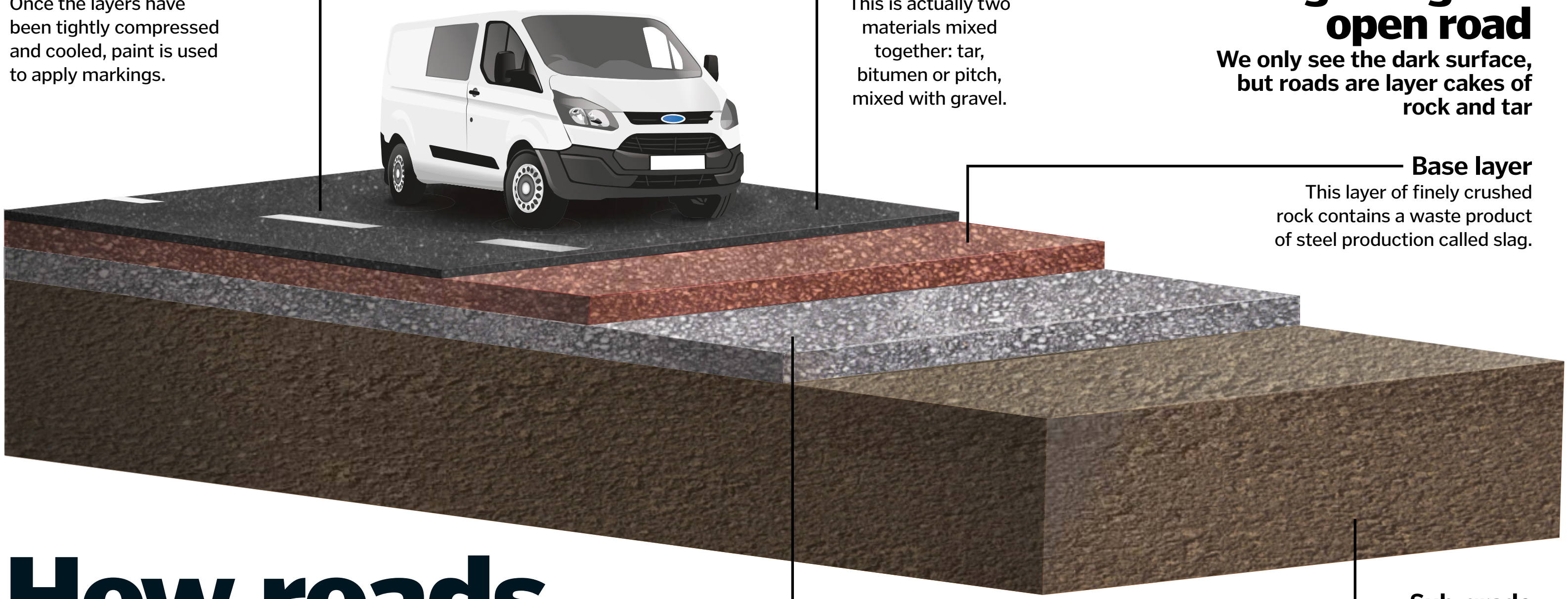

Unmanned aerial vehicles like the MQ-9 Reaper can carry out missions via remote control

How roads are made

The construction process is more complex than you might think

Rolling along the open road

We only see the dark surface, but roads are layer cakes of rock and tar



It's believed that the first roads paved with bricks were constructed in the Indus Valley more than 5,000 years ago. Today, there are enough roads on Earth to circle the planet over 600 times, but bricks are no longer the material of choice. In fact, modern roads are built using layers of different materials.

Vehicles are heavy – a typical family car weighs well over a ton – which means that roads have to be tough enough to withstand the stresses involved. That's why the load is spread over four layers. At the bottom is the sub-grade – this is the local soil that is compressed with a roller. Next, you have the sub-base, typically made from crushed concrete. The base comes next – another layer of finely crushed rock mixed with asphalt and slag, which is a waste product from steel production. Then comes the smelly stuff – the binder and surface materials, collectively called tarmacadam. The 'tar' is the hot, sticky black substance, and 'macadam' is the gravel that is densely packed into the tar using a roller. Once it has cooled down, the road is complete.

Each layer of material needs to be compressed by a roller to strengthen it

Cat's eyes explained

Discover exactly how these reflective patches mark out a driver's route in the dark

Invented by Yorkshireman Percy Shaw, 'cat's eyes' are reflective markers found on roads across the world. Their name was inspired by the eerie glow given off by the eyes of cats and other nocturnal hunters when a light is shone on them. In cats, this reflectivity is due to a layer of silvery-green tissue at the back of their eyes – as well as reflecting light, it helps cats to see in the dark.

To reproduce this effect, cat's eye road markers use two tiny studs, made from lozenge-shaped glass beads that have one end coated with an aluminium mirror. As the light from a vehicle's headlamps enters the front of the glass beads, it bends slightly, reflects off the mirrors, and bounces back into the driver's eyes.

Cat's eyes are ultra-durable too. The mirrored beads are set into a tough rubber dome, which is surrounded by a ring of cast iron. If a vehicle drives directly over it, the rubber dome briefly sinks into the road, but bounces back unscathed. Cat's eyes can be produced in any colour – white, yellow and green are the most common.

Cat's eyes are the simplest, power-free way to mark roads in the dark

How the Sailrocket 2 works

Find out how this boat hits such high speeds on the high seas

The design of the Sailrocket 2 perfectly balances forces for speed

When it comes to going super fast on water, powerboats are usually the go-to craft. However, there's one sailboat out there that is capable of achieving breakneck speeds of 65 knots (120 kilometres per hour) using wind power alone. It's called Sailrocket 2, and it's the brainchild of Paul Larsen, based on designs originally by an American rocket engineer in 1917.

The Sailrocket 2 is an aerodynamic mixture of plane and boat. Its ingenious design relies on a mixture of forces to keep it stable and to transfer the energy from the wind (that would cause a normal boat to capsize) into extra speed.

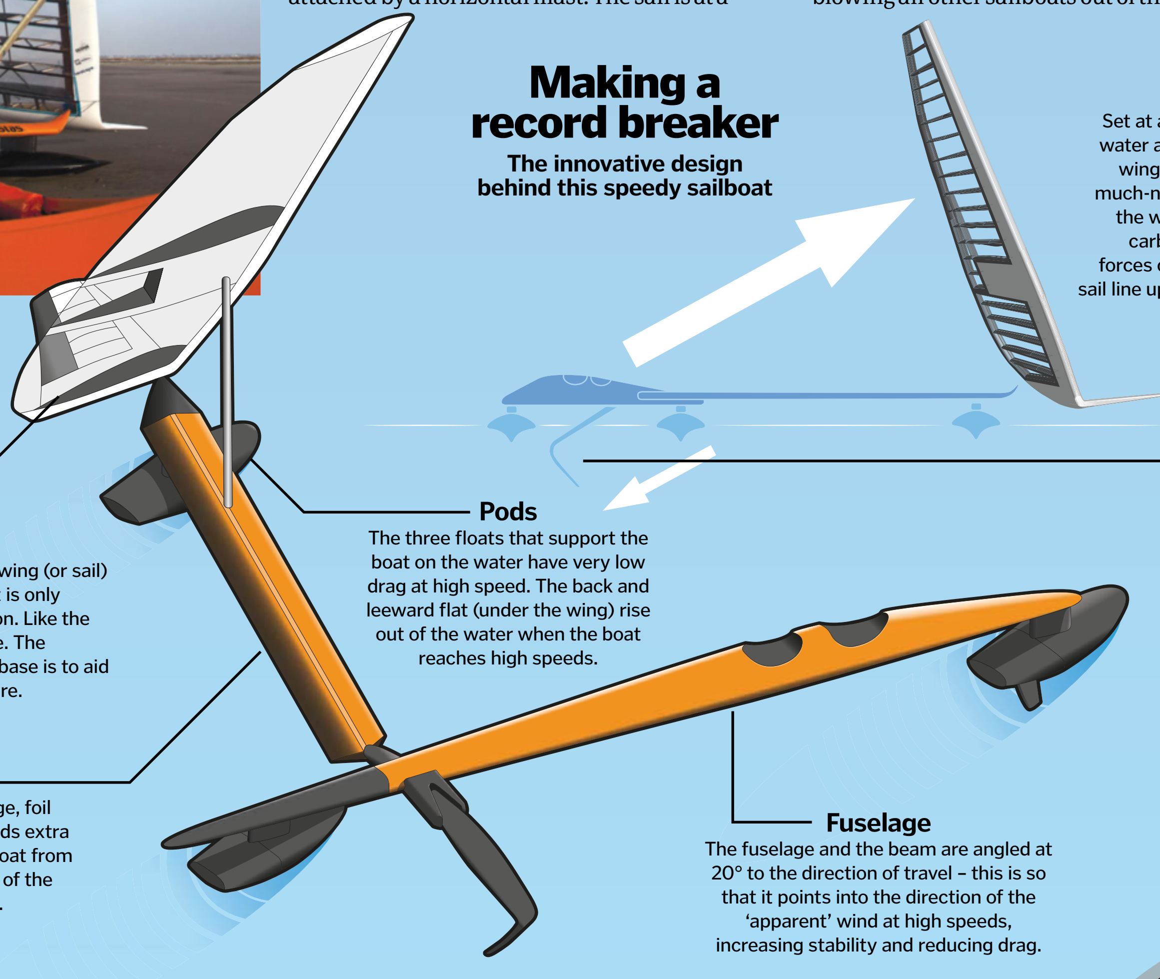
The cockpit (fuselage) sits parallel to the sail, attached by a horizontal mast. The sail is at a 30-degree angle to the water, and protruding from the cockpit is a bent carbon-fibre keel, or foil. The whole boat sits on the water atop three pods.

The foil is the real genius in this design; it's tough but thin, and helps to create minimum drag while stabilising the entire boat. It also counteracts cavitation (bubbles that cause drag) using a wedge-shape design that reduces the friction in the water caused by the phenomenon.

When the boat hits 50 knots (92 kilometres per hour), buoyancy is replaced by hydrodynamic lift. Two of the boat's pods lift out of the water, and it glides on pockets of air trapped between the pods and the water. The foil keeps it stable, allowing the Sailrocket 2 to reach record speeds, and blowing all other sailboats out of the water.

Making a record breaker

The innovative design behind this speedy sailboat



Foil
Set at a 30° angle in the water and parallel to the wing, the foil provides much-needed stability in the water. It's made of carbon fibre, and the forces of the foil and the sail line up for extra speed.

Pods
The three floats that support the boat on the water have very low drag at high speed. The back and leeward flat (under the wing) rise out of the water when the boat reaches high speeds.

Wing
Super light and strong, the wing (or sail) is asymmetrical as the boat is only needed to go in one direction. Like the foil, it is tilted at a 30° angle. The horizontal extension at the base is to aid lifting and distribute pressure.

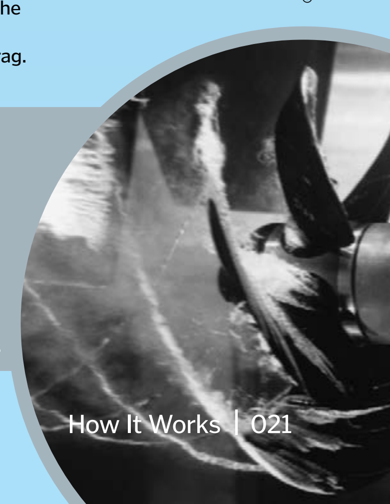
Beam
The beam keeps the fuselage, foil and the sail apart, which adds extra stability and prevents the boat from leaning. This means that all of the energy is focused on speed.

Fuselage
The fuselage and the beam are angled at 20° to the direction of travel – this is so that it points into the direction of the 'apparent' wind at high speeds, increasing stability and reducing drag.

What is cavitation?

Cavitation is essentially the formation of bubbles (air pockets) in a liquid when it is under extremely high pressure. This happens when a foil cuts through water at speeds higher than the so-called '50-knot barrier' (the equivalent of 93 kilometres per hour). The phenomenon is not fully understood, but it causes the seawater to vaporise and form intense bubbles – a little like boiling. This causes drag and prevents the boat from accelerating.

Breaking the 50-knot barrier is difficult because the foil has to be small and light enough to enable the boat to go fast, but a smaller foil means a greater pressure change and more cavitation. To combat this, instead of a smooth, wing-like design, Sailrocket 2's foil uses a wedge-shape to cut through the water and leave a smooth pocket of air in its wake, instead of a mass of chaotic bubbles.



As a spinning propeller cuts through the water, cavitation bubbles form at the blades

OLYMPIC GAMES SCIENCE

REVEALED: THE SCIENCE & TECH BEHIND RECORD-BREAKING SUPERHUMANS

In 1896, when the first games of the modern Olympics were held in Athens, only 14 nations competed. Irishman John Pius Boland was there as a spectator but won both the singles and doubles tennis competitions after a friend entered his name. Meanwhile, the marathon was won by Spiridon Louis of Greece, even though he stopped halfway to eat an egg and drink a glass of wine! In the 120 years since then, the Olympic games has grown to a multibillion-pound global event. In Rio this summer more than 10,000 athletes will compete for 306 gold medals across 42 Olympic sports.

Since 1900, the average height for men in the UK has increased by about ten centimetres, mostly due to better nutrition. This extra height accounts for a significant portion of the increase in sporting performance. The rest, however, is down to science. A better understanding of sports nutrition has enabled athletes to tailor their diet during training so they can build muscle mass, increase bone density and reduce body fat. Sports medicine has developed training regimes that allow athletes to train closer to their physical limits without injury and recover more quickly from tissue damage that at one time would have knocked them out of contention. Advances in materials science have led to new composites for shoes and equipment that are light without compromising strength, and fabrics that recover the rebound energy from each movement, while efficiently dissipating the heat generated by the athlete's exertions.

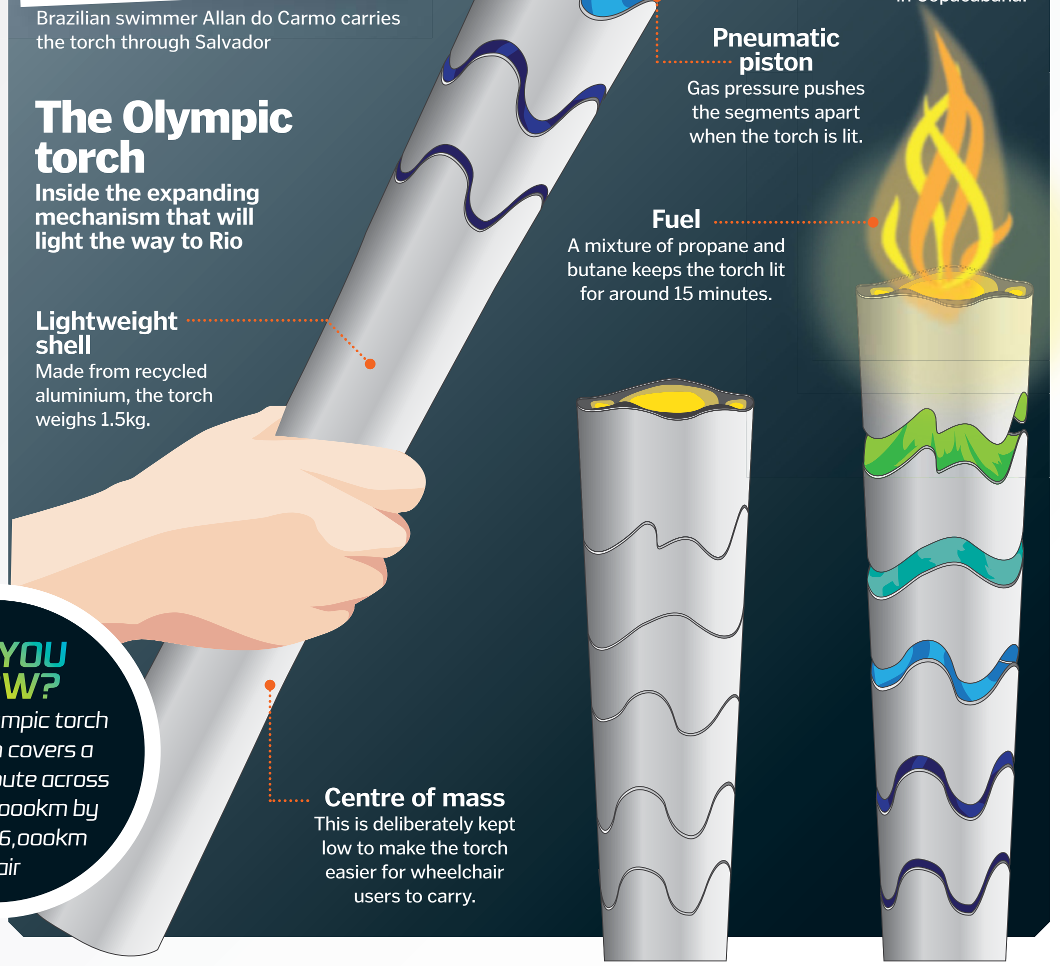
In 1968, when Dick Fosbury invented a new way to clear the high jump, by leaping backwards over the bar, the advantage was so obvious that virtually every other high jumper immediately began copying it. But modern high-speed cameras and 3D modelling software have since allowed coaches to spot tiny errors in each limb movement and push athletes to grind away at these imperfections until every performance resembles a symphony of muscular coordination.

One thing science can't correct is the home crowd advantage. The patriotic spur that helped Team GB land 65 medals in the London Olympics – more than every nation apart from the US and China – will be sorely missed in Rio this year. But it just might give Brazil the boost it needs to improve on the 17 medals it won in 2012.

Brazilian swimmer Allan do Carmo carries the torch through Salvador

The Olympic torch

Inside the expanding mechanism that will light the way to Rio



DID YOU KNOW?
The 2016 Olympic torch procession covers a 36,000km route across Brazil – 20,000km by road and 16,000km by air

> "Every Olympic performance resembles a symphony of muscular coordination"

The Olympic flame is first lit by the focused rays of the Sun, in Greece

The torch relay will visit 329 Brazilian towns and cities

TRAINING AND PREPARATION

What does it take to reach the pinnacle of human physical condition?

Olympic triathletes start every day with an hour of swimming

Olympic athletes are always either training or competing; there is almost no downtime. Their diet consists of complex carbohydrates and lean proteins with small meals every three to four hours. It's also important to eat within 90 minutes of each training session to provide the fuel and building materials the body needs to grow new muscle. During intensive exercise, athletes need to drink one litre of water for every 50 kilograms of body weight and this has to include the right concentration of electrolytes to replace those lost through sweat.

The Olympic stadiums in Rio are all close to sea level but high altitude training is still an important technique. The lower oxygen concentration at high altitudes forces the bone marrow to produce extra red blood cells and studies have shown that it also improves the way muscles are able to metabolise oxygen in the blood stream. British Olympic champion Mo Farah spent several weeks at a training camp in Addis Ababa, Ethiopia, at an altitude of 2,300 metres – that's almost twice the altitude of Ben Nevis, the highest mountain in the UK.

August is the middle of winter in Rio, but temperatures can still be as high as 29 degrees Celsius. Even more significant is the relative humidity, which averages 80 per cent throughout the month, with a brief dip in the mid-afternoon. Olympic athletes prepare for these conditions with six to ten days of acclimatisation training before the start of the games. They aim to push their core body temperature up to 38.5 degrees Celsius for at least 30 minutes per session to reset the body's thermoregulation mechanisms to the local conditions.

What is doping?

Performance enhancing drugs were first banned in the 1968 Mexico City games and there has been a steady increase in the number of athletes caught cheating since then. The number of banned substances now stands at around 300, but there are other illegal techniques that don't involve drugs too. Blood doping involves removing some of the athlete's blood weeks before the event, then transfusing the red blood cells back just prior to competing, to boost oxygen uptake and endurance. Gene doping uses viruses to insert high-performance genes into certain cells in the body. Although these techniques are harder to detect than simple drug use, the World Anti-Doping Agency keeps samples for ten years and continually retests old ones as new techniques emerge. In May this year, 32 athletes from 12 countries were banned from the Rio games after stored samples from the 2008 Beijing games were retested.

Athletes can be retroactively disqualified ten years after a doping offence

Mental preparation is also vital to success. Nerves and self-doubt can severely affect a competitor's coordination and muscle performance – and cost them the gold medal. Athletes work with sports psychologists to learn how to visualise themselves succeeding, in order to overcome these mental inhibitions.

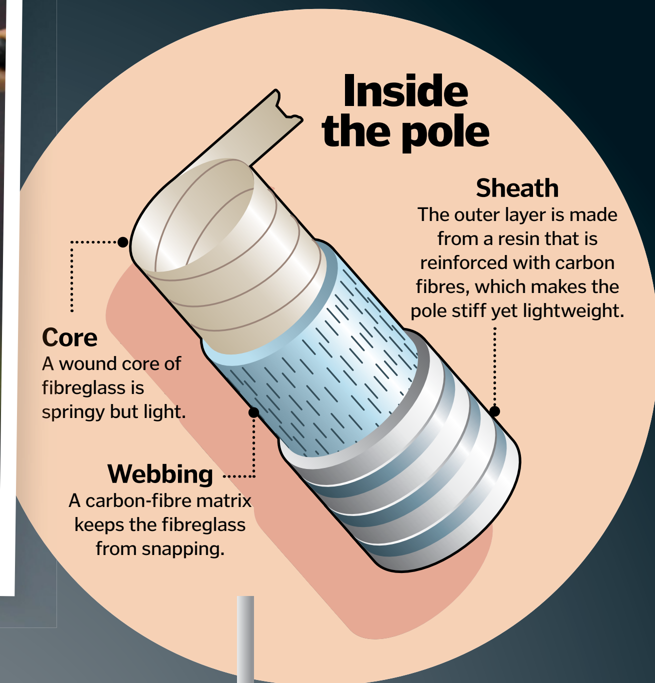
Athletes also train while listening to recorded crowd noise, to practise tuning these distractions out once and for all. Superstitions, such as kissing a crucifix or wearing lucky underpants, can also have a calming effect that is just as real and scientifically measurable as the placebo effect during drug trials. Rather than trying to eliminate it, athletes can actually harness these mind games to keep themselves fresh and focused.

Training diary

A typical day for British Olympic triathlete Helen Jenkins

05:00	Wake up, eat one slice of toast and then drive to the pool.
05:30	90 minutes of intensive swimming with a swim coach.
07:15	Eat toast with Philadelphia and jam, drink tea and take multivitamins.
09:00	Take a quick nap, which helps to aid muscle recovery.
11:00	2.5 hours of cycling training, followed by a snack bar.
13:30	Eat lunch of salad, tuna and couscous, followed by yoghurt.
15:00	Rest, watch television, check emails and do some stretching.
17:00	One-hour run, followed by a protein and carbohydrate recovery drink.
18:30	Eat dinner of chilli with vegetables and rice, and a hot chocolate.
19:30	Rest, then an early night before it all starts again in the morning!

Yelena Isinbayeva is a two-time Olympic Gold medallist and the current world record holder



POLE VAULT

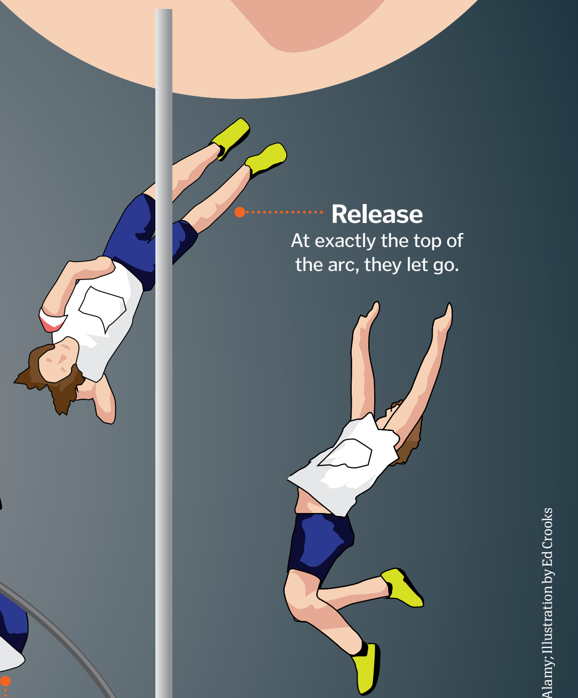
How to turn a 40-metre sprint into a six-metre leap

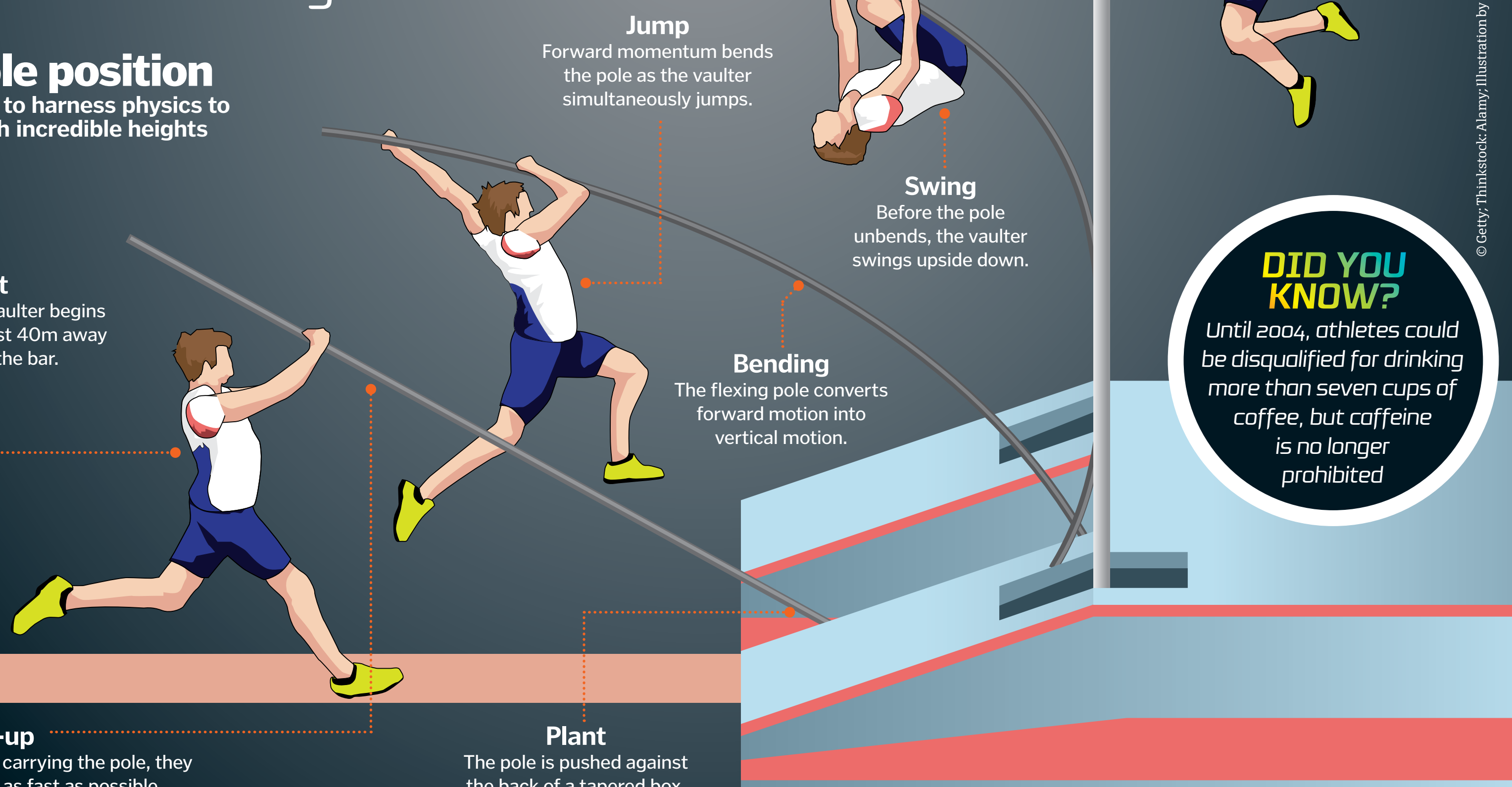
A common misconception is that a pole vaulter uses their upper body strength to pull themselves up the pole but this event is actually a test of speed and agility more than super-human strength. Almost all of the energy for the vault comes from the initial run-up. The springy pole acts as a battery to store this forward movement as it bends. In the time it takes the pole to spring back, vaulters must swing themselves up so that their body is upside down and vertical. The pole releases its energy as upward movement, propelling the vaulter over the bar.

"Athletes push their core temperature to 38.5 degrees Celsius in training"

Pole position

How to harness physics to reach incredible heights





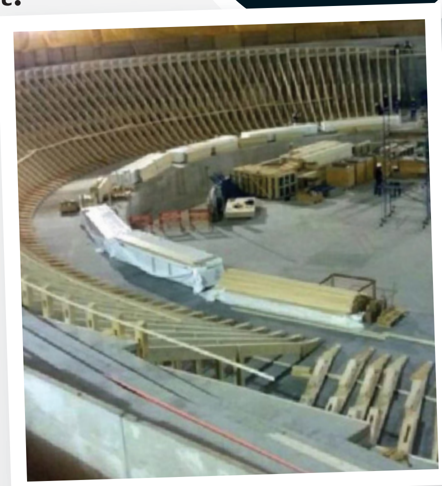
DID YOU KNOW?
Until 2004, athletes could be disqualified for drinking more than seven cups of coffee, but caffeine is no longer prohibited

TRACK CYCLING

The event where the fastest rider is the one that starts out slowest!

Cycling is the fastest Olympic sport. Around the indoor velodrome track, riders can reach 74 kilometres per hour. Success in sprint cycling is as much about strategy as strength. At these speeds aerodynamic drag is the dominant force and sprint events often begin with the two riders trying to move as slowly as possible to force their opponent out in front, to create a slipstream for the following rider. The lead rider in turn may hug the red sprinting line around the track, rather than the shorter black line, to force an overtaking rider to waste energy climbing higher up the banked track.

DID YOU KNOW?
As they race round the banked curves, a 100kg cyclist will weigh an extra 70kg due to centrifugal force!



London's Olympic velodrome used 338,000 nails, hammered by hand to ensure a smooth surface

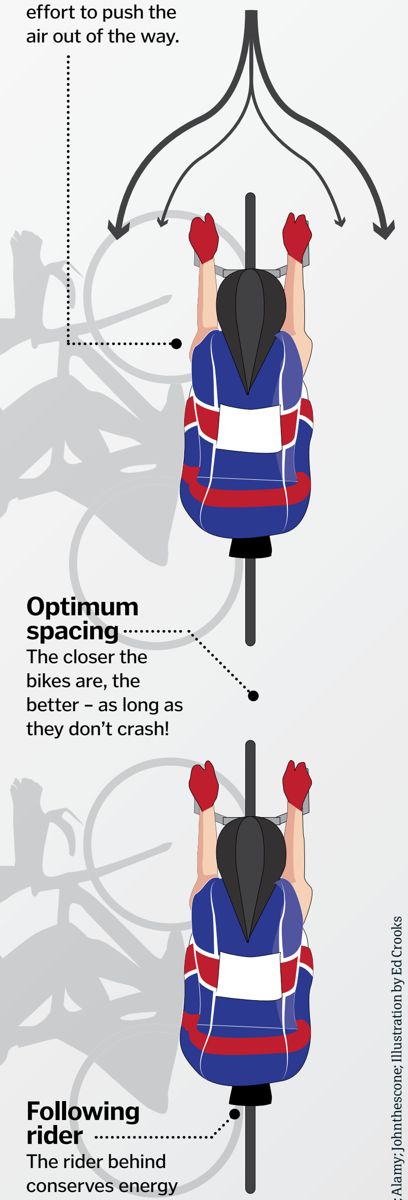
This is what Rio's velodrome looked like under construction. It was the last stadium to be completed

Slipstreaming

In cycling races, the lead rider has to work the hardest. Not only must they expend energy to push the air out of the way, but the gap in the air creates a low pressure zone behind the bike that sucks them backwards. If the rider behind is close enough, they can exploit this low-pressure zone to reduce their own effort. This actually lowers the effort by around five per cent for the leader as well, because of reduced turbulence. But the effect for the second-place rider is much greater, saving as much as a third of their energy.

Exploiting aerodynamics

The less time you spend in the lead, the more likely you are to win!

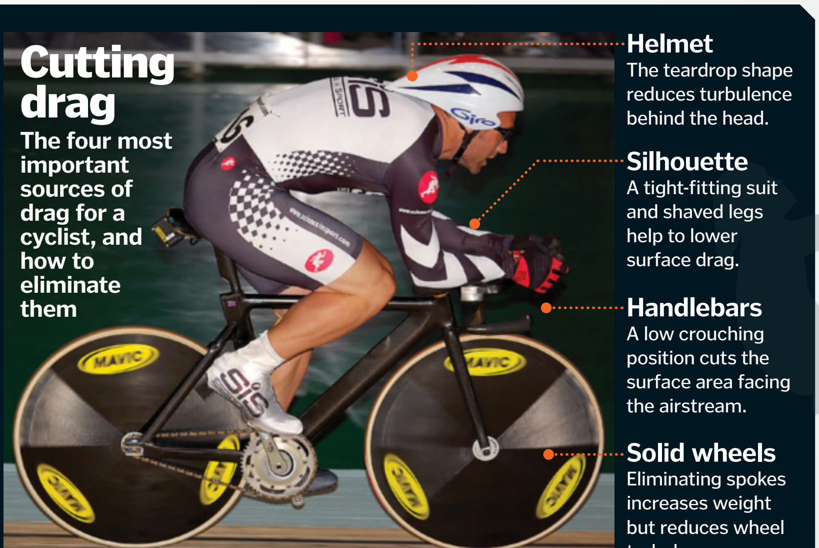


Designing away drag

70 per cent of a cyclist's effort is spent fighting aerodynamic drag. Three quarters of this drag comes from the cyclist themselves, but even small improvements to the design of the bike can have a big effect. The bike frame alone accounts for up to nine per cent of the total drag and just using spars with an elliptical – rather than circular – cross section can shave a few percent off this. The Cervélo T5GB bike that will be used by Team GB in Rio also has a rear spar that curves to follow the back wheel. This is likely to reduce turbulence by helping the air to flow smoothly past the bike.

Cutting drag

The four most important sources of drag for a cyclist, and how to eliminate them



TECHNOLOGY AT THE OLYMPICS

Even 3,000-year-old sports can still find room for high-tech tweaks

Olympic athletes are constantly looking for high-tech equipment to maximise their performance, but each event has different regulations about what is permissible. The pole vault is one of the least regulated; vaulters can use poles made of any material and of any length. Olympic swimmers, on the other hand, can't even wear swimsuits that reach below the knee or which include zips or fasteners. These rules were introduced after the 2008 Beijing Olympics, where the Speedo LZR suit was first used. This was made from a more rigid material that mimicked shark skin to reduce drag, and included air pockets to improve buoyancy. It was so effective that 23 of the 25 world records broken in Beijing were by swimmers wearing the LZR. Under the new rules, suits like these are banned.

As well as ensuring a fair competition, technological improvements are sometimes banned for safety reasons. The design of the Olympic javelin was changed in 1986 to make it fly less well. This was because javelin throws were beginning to exceed 100 metres and there was a real danger that they would soon overshoot the stadium and land in the crowd! Technology can improve safety in other ways, too. The South Korean Olympic team will wear training outfits impregnated with mosquito repellent to guard against the threat of the Zika virus.

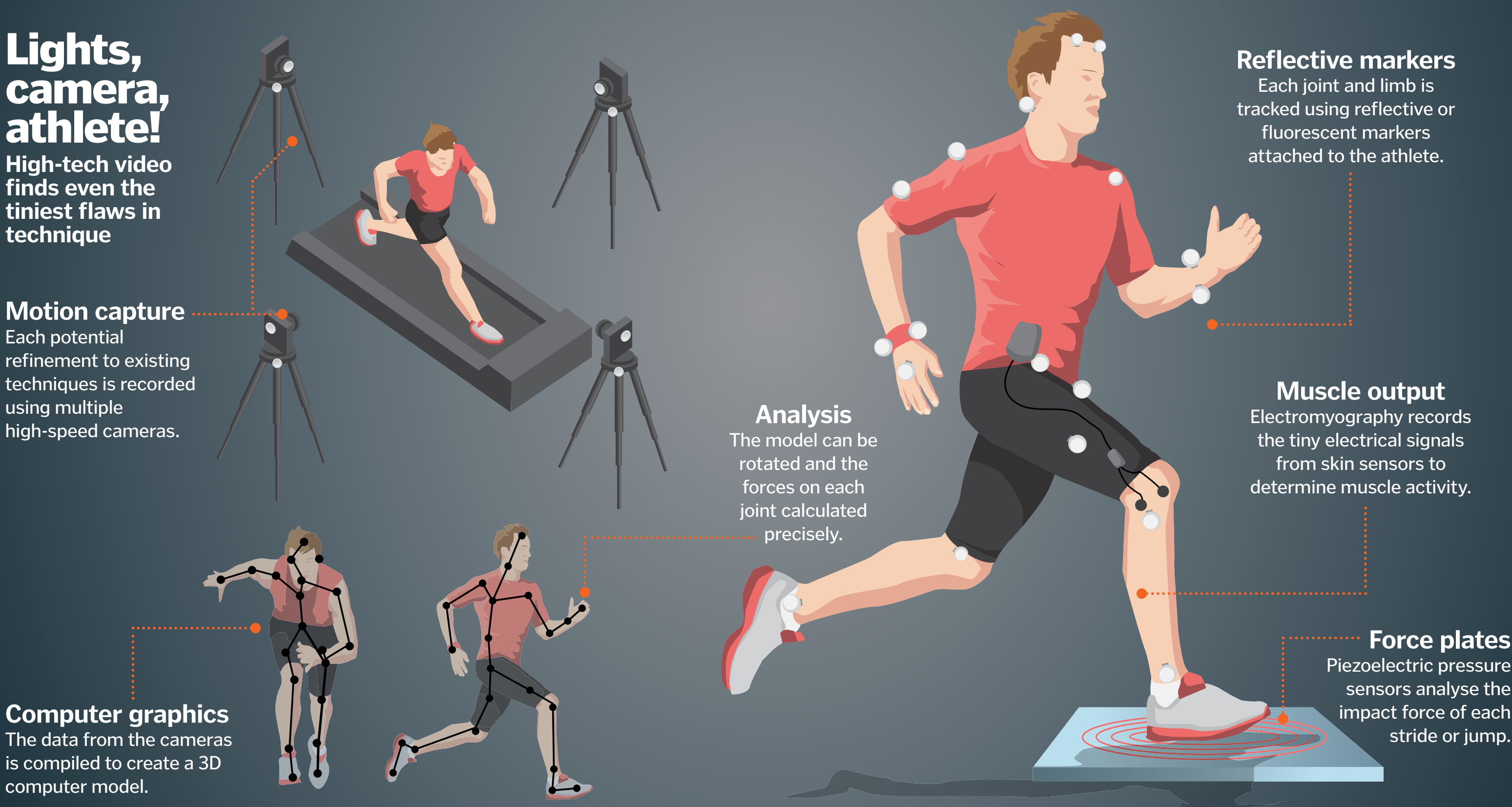
At Rio this summer, video technology will be deployed on an unprecedented scale for Brazil. Drone cameras will provide new vantage points, live telemetry data will be available via phone apps and road cycling teams will use special sunglasses with head-up displays, giving them real-time speed and pacing information.

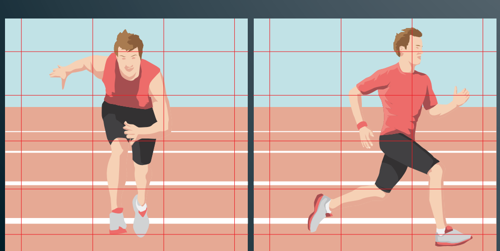
Gadgets can make sports fairer, too. In London 2012, Sarah Stevenson initially missed out on a bronze medal for taekwondo after a decisive blow wasn't scored by judges. In Rio, for the first time, taekwondo participants will use special magnetic socks that register hits automatically.

The IT infrastructure needed to connect all this together is enormous. In June, the Technology Operations Centre in Rio held a huge technical rehearsal of the three days of events they expect to be busiest. Almost 1,000 different scenarios were simulated, including flood, power failure and terrorist attacks, to check that the computer systems could still operate across all 22 Olympic venues.

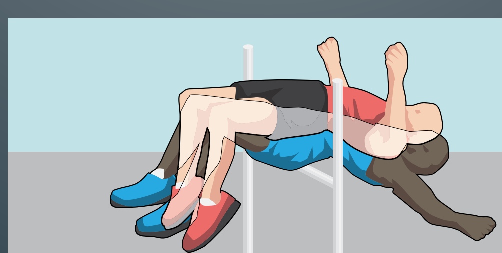
Lights, camera, athlete!

High-tech video finds even the tiniest flaws in technique

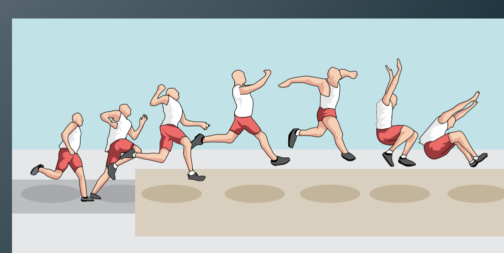




Synchronised views
By filming from two or more angles and then playing them back in synchronised split frames, the athlete can analyse their movement in great detail. Computer drawings can highlight the angle of each limb.



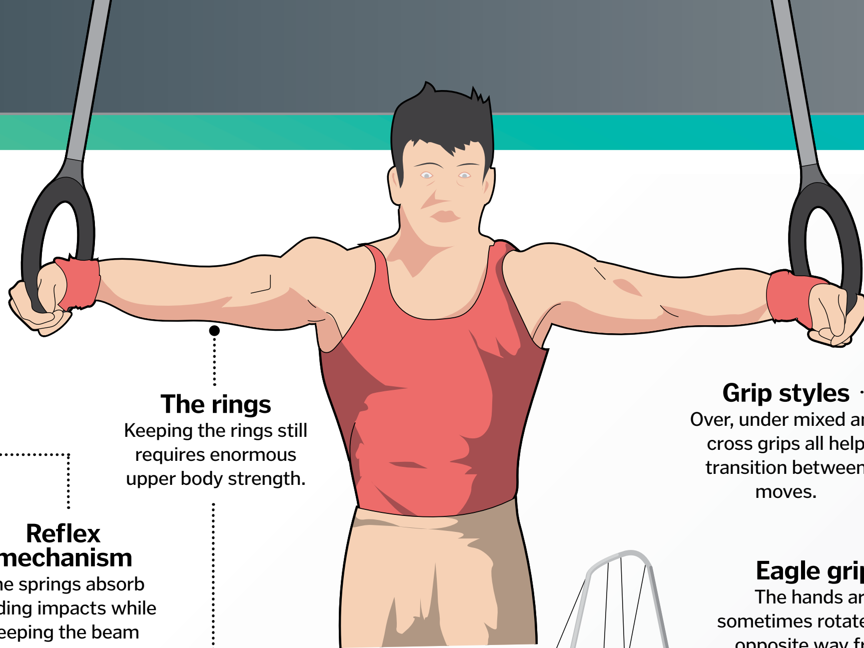
Video mixing
To compare multiple attempts from the same athlete, or a rival's world record performance, the video can be merged. This makes it much easier to spot tiny differences in timing or posture.



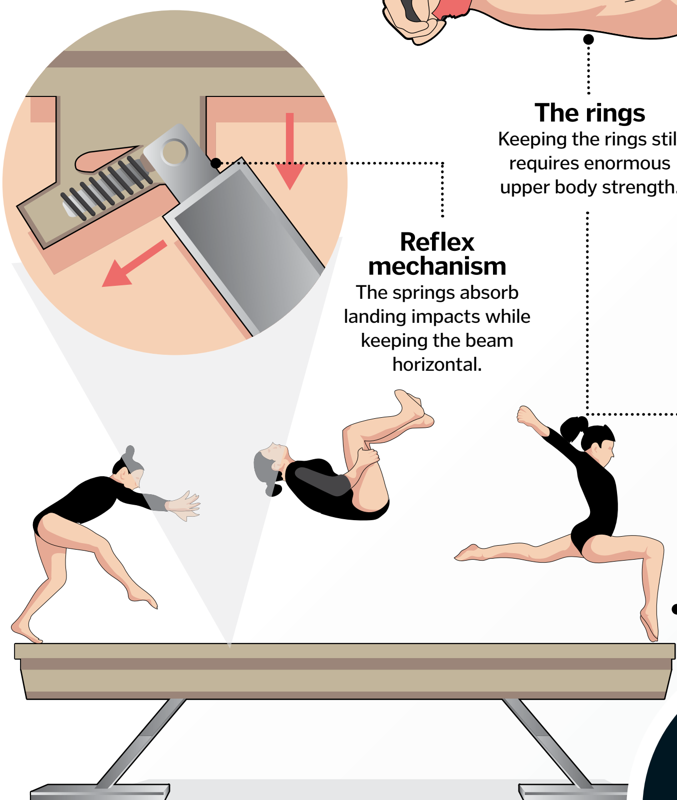
Freeze frames
A rapid strobe flash can capture a series of freeze frames overlaid on a single image. This turns a fast moving event into a static sequence for analysis.

Floor physics

Gymnasts exploit Newton's laws to produce impressive routines

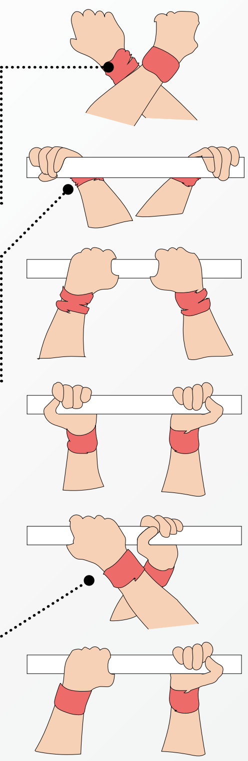


The rings
Keeping the rings still requires enormous upper body strength.



Reflex mechanism
The springs absorb landing impacts while keeping the beam horizontal.

Balance beam
Gymnasts must land precisely, keeping their centre of gravity over the beam.



Grip styles
Over, under mixed and cross grips all help transition between moves.

Eagle grip
The hands are sometimes rotated the opposite way from normal, which requires extra flexibility!

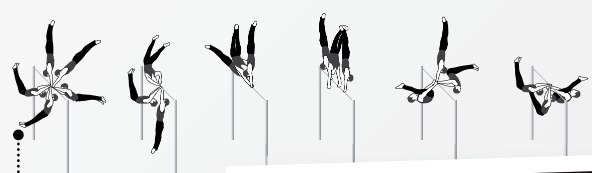
Grips
Leather pads on the palms (secured with wrist straps) provide friction, giving a good grip on the bars.

DID YOU KNOW?
The five rings on the Olympic flag represent the inhabited continents: Africa, Asia, Europe, Oceania and the Americas

GYMNASTICS

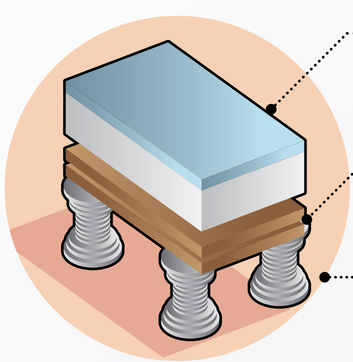
Newton's fourth law of gymnastics: thou shalt dismount cleanly

Gymnastics is ultimately about converting linear motions into rotational motions, and rotational motions into linear ones. When the vaulter plants their hands on the vaulting horse, friction with the surface creates a torque that helps accelerate their body around in a somersault. The flying transition from one bar to the next in the uneven bars is powered by the angular momentum built up from the swing before. Olympic equipment is designed to be as springy as possible to allow gymnasts to recover the maximum energy from each move, so more is available to power high leaps and fast tumbles.



Uneven bars
The springy bars convert downswing momentum into increased rotational speed.

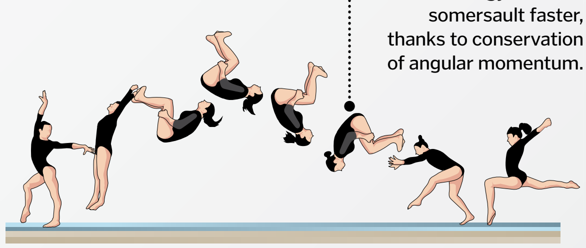
Gymnasts require immense upper body and core strength



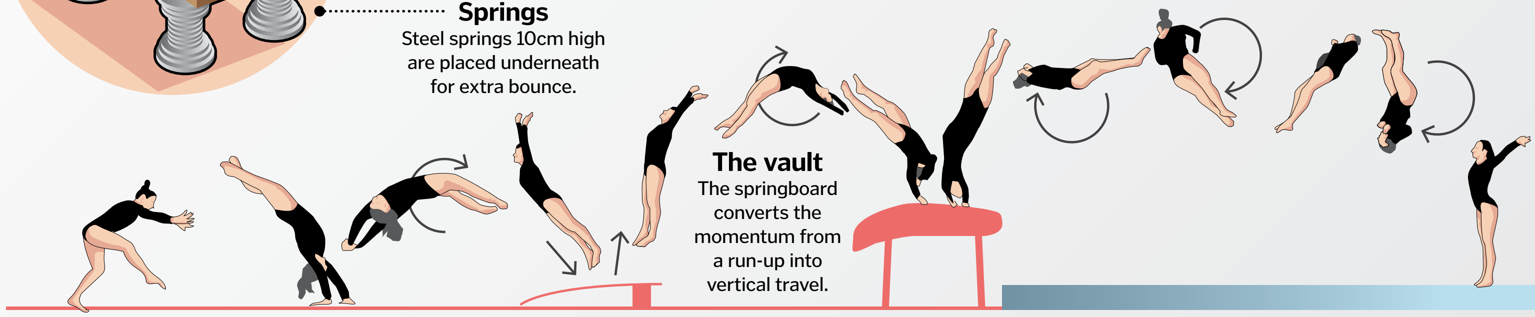
Top layer
Rio's bright green gymnastics floor is backed with 4cm of foam.

Wooden floor
Springy plywood forms the base, to ensure a level display area.

Springs
Steel springs 10cm high are placed underneath for extra bounce.



Tumbling
Tucking in the legs allows the gymnast to somersault faster, thanks to conservation of angular momentum.



The vault
The springboard converts the momentum from a run-up into vertical travel.

The modern Olympic javelin has the balance point further forward, so it sticks in the ground

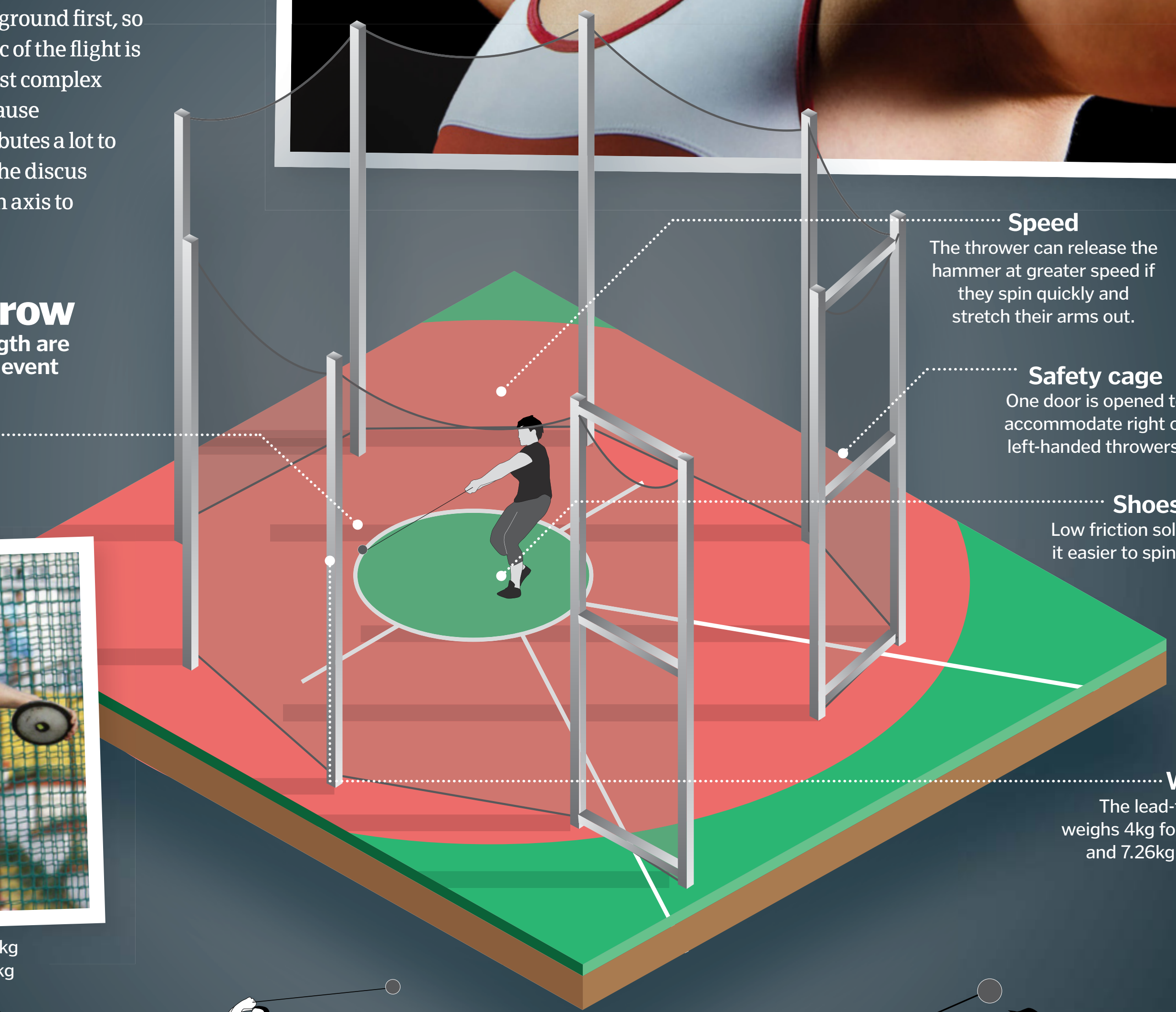
THROWING FOR GOLD

The four Olympic throwing events are a lot more complicated than you think

The hammer throw is tricky to master but the physics are simple: angular momentum is built up during a spin and then released. The shot put combines the angular momentum from an initial turn with a linear push at the moment of release. For the javelin, a legal throw requires the tip of the javelin to strike the ground first, so correctly judging the arc of the flight is also important. The most complex event is the discus, because aerodynamic lift contributes a lot to the final distance and the discus must be spun on its own axis to keep it stable in flight.

Hammer throw

Both speed and strength are key to success in this event



Steel wire
This is 3mm thick, 119.5cm long for women or 121.5cm for men.

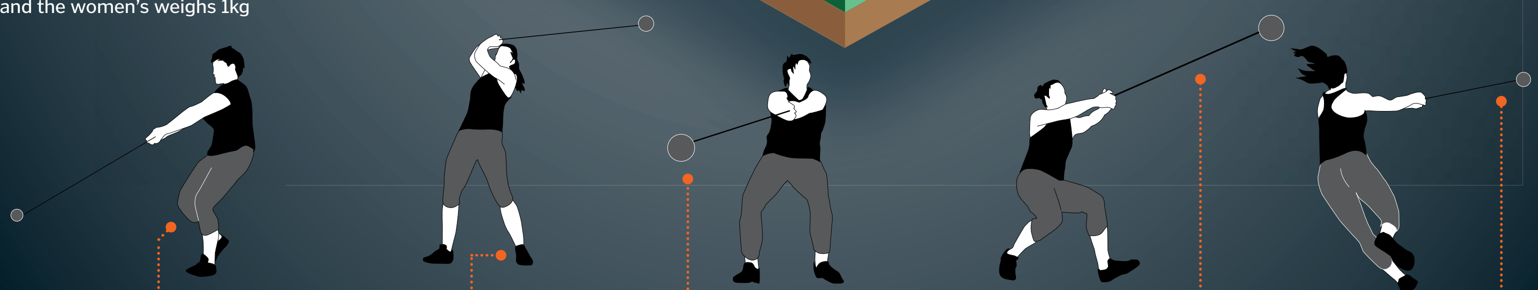
Speed
The thrower can release the hammer at greater speed if they spin quickly and stretch their arms out.

Safety cage
One door is opened to accommodate right or left-handed throwers.

Shoes
Low friction soles make it easier to spin around.

Weight
The lead-filled ball weighs 4kg for women and 7.26kg for men.

The men's discus weighs 2kg and the women's weighs 1kg



Start
The thrower begins at the back of the 2.135m throwing circle, with their back to the throwing sector.

Preparation swing
To get the hammer moving, the thrower takes two swings up and over their head, with both feet firmly planted.

Transition
Now they make three or four turns with their body, pivoting on the left foot and spinning the hammer horizontally.

Build momentum
The thrower increases speed each time their right foot hits the ground, and begins to raise the angle of the hammer.

Release
The hammer is released and travels out of the cage. The thrower will aim to release it at a 43-degree angle.

CLEARING THE BAR

Using science to cheat gravity for the longest leaps and highest hops

Jumping events work like the throwing events, except that the athlete is the projectile! The basic physics remains the same; a sprinting run-up creates kinetic energy, which is diverted into an upward ballistic arc by the take-off jump. Long jumpers and triple jumpers use a shallow 20-degree take-off angle because most of the energy comes from the forward motion. High jumpers arch their body backwards as they sail over the bar to keep their centre of mass as low as possible – in fact, their centre of mass is even lower than the bar itself. This means it takes less energy to clear a bar of a given height.

Long jumpers throw their hands forward to avoid rolling backwards

A high jumper arches their back to keep a low centre of mass

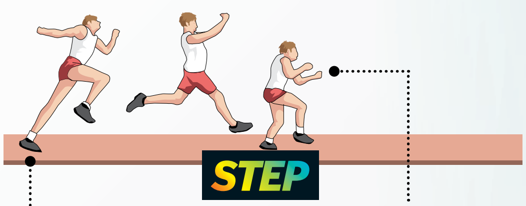
DID YOU KNOW?
Athletes at the Ancient Olympics in Greece ate a diet of mostly fruit and cheese and competed in the nude!

The triple jump

The triple jump needs perfect timing to preserve momentum

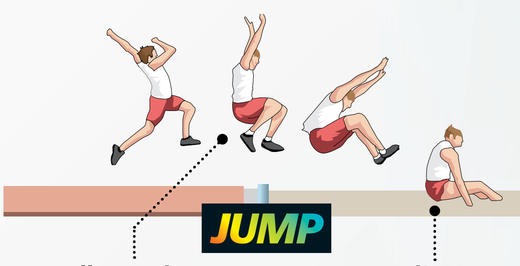
Approach
After a 20 or 22 stride run-up, the jumper launches on their strongest foot.

Right leg
The angle of the hop mustn't be too steep, so that the leg can quickly take off again.



Angle
The athlete must take off at a higher angle than the hop to cover a large distance.

Arms
The arms swing forward before landing to get ready for the final jump.

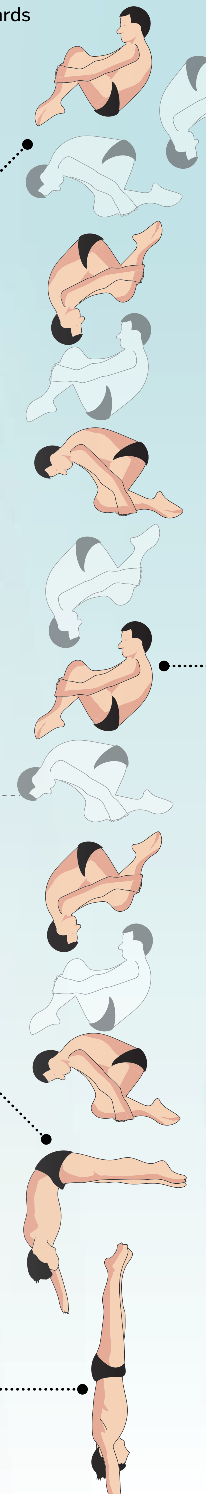


All together
Both legs thrust forward, together with the momentum from swinging arms.

Landing
The athlete brings their arms forward and rolls sideways to avoid falling back.

The high dive

How to make a big impression by creating a small splash



Jump
Turn sharply at take-off to generate angular momentum.

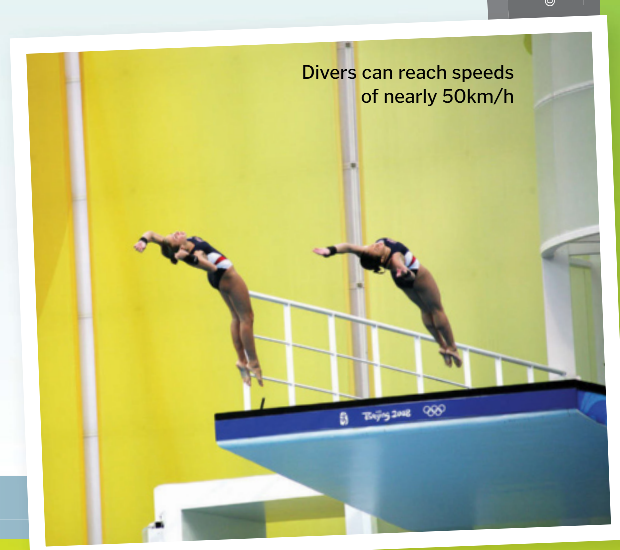
Tuck
Pull in knees to increase rotation, by conservation of angular momentum

1.8 seconds
There is just enough time for 4.5 somersaults.

"Jumping is like throwing, but the athlete is the projectile!"

Straighten
Present the smallest cross-section for the smallest splash.

Rip
Hit the water at 48km/h, as smoothly as possible.



Divers can reach speeds of nearly 50km/h

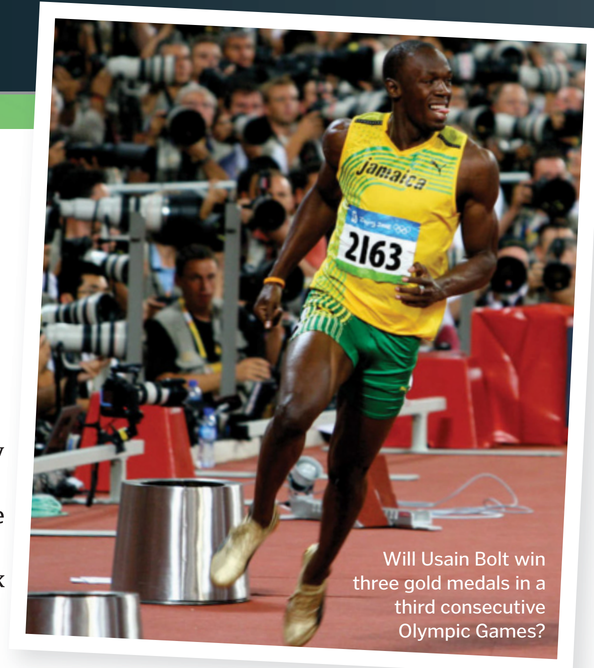
TRACK EVENTS

There is still room for tech in even the most natural sport

There are 12 running events in the Olympics, including two hurdles races, the 3,000-metre steeplechase and two relays. Since the training and techniques are similar, it is common to see athletes competing in both the 100 and 200-metre, or the 5,000 and 10,000-metre races.

Track athletes are allowed to run barefoot but it is rarely done, as running shoes usually offer a performance advantage. A carbon-fibre sole plate is much springier than the human foot, and so recovers more energy from each stride. More extreme designs that feature actual springs in the heel do exist, but these are currently banned by the IAAF.

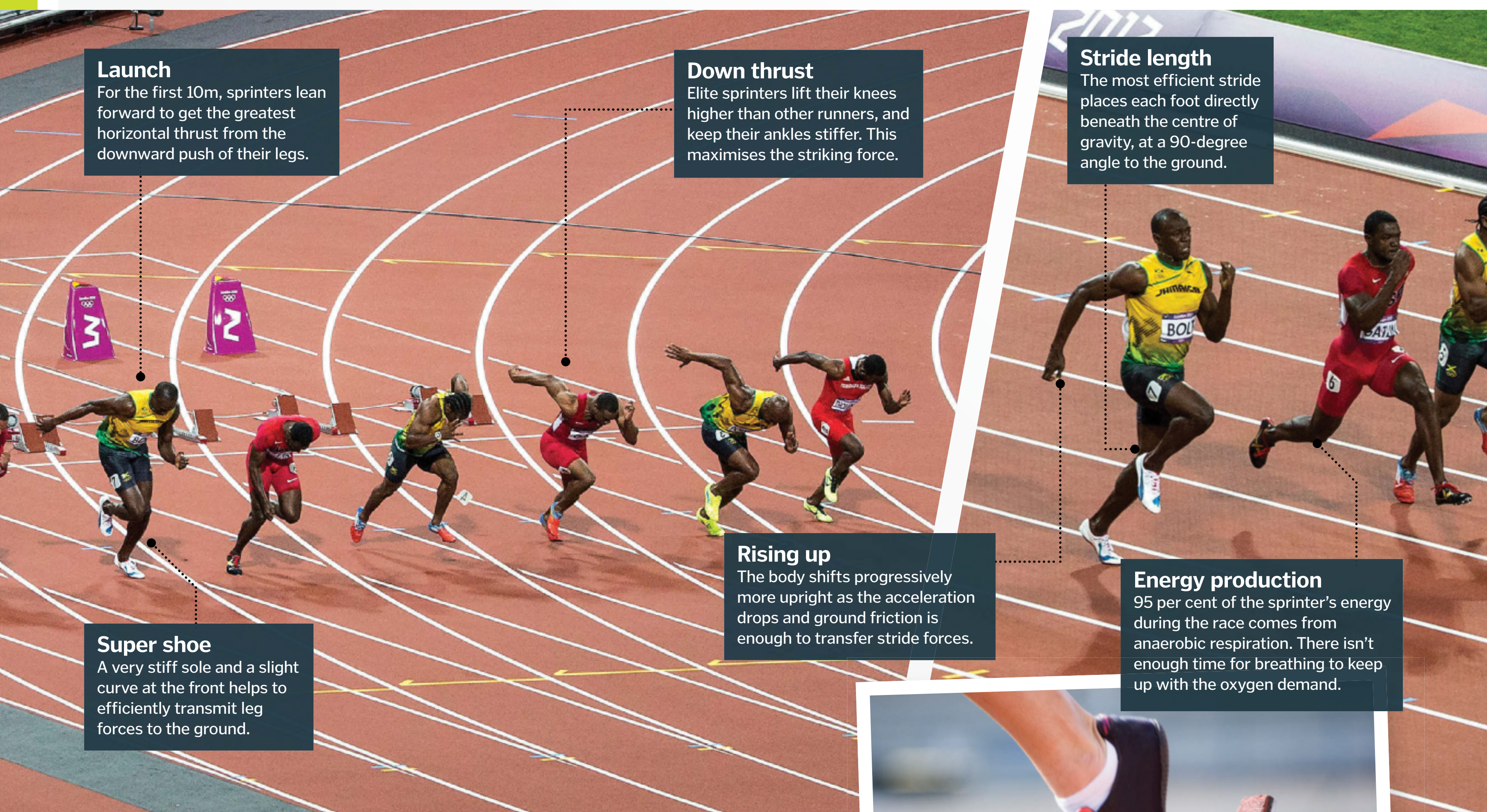
The disadvantage of running shoes is that they add weight, which must be accelerated on each stride. However, high-tech shoes such as the Nike Flyknit are woven from continuous strands of high tensile yarn so that they are more like a sock than a shoe, and weigh just 160 grams each.



Will Usain Bolt win three gold medals in a third consecutive Olympic Games?

The 100-metre sprint

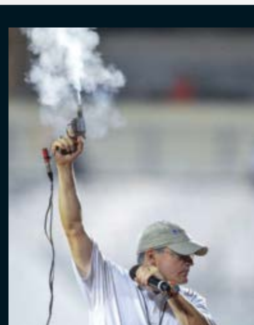
The shortest Olympic running event is also one of the most exciting




An explosive start is critical in any 100m race

Split second start

The traditional starter's pistol might seem like a fair way to begin a race, but it's not accurate enough for the Olympics. It takes three milliseconds for the sound of the gun to travel one metre, so the runner in the inside lane would hear the start a split second before the one in the outside lane. To avoid this, sprint events use an electronic gun that relays a signal instantly to speakers built into each set of starting blocks. The start signal is also connected to pressure pads in the starting blocks that can detect anyone taking off before they could possibly have heard the start. At the finish, the main scoreboard times are stopped automatically when the runner breaks a light beam. However, the official times are confirmed by checking the image from a line-scan camera that timestamps at 10,000 frames a second!


Even starter pistols have had a high-tech makeover

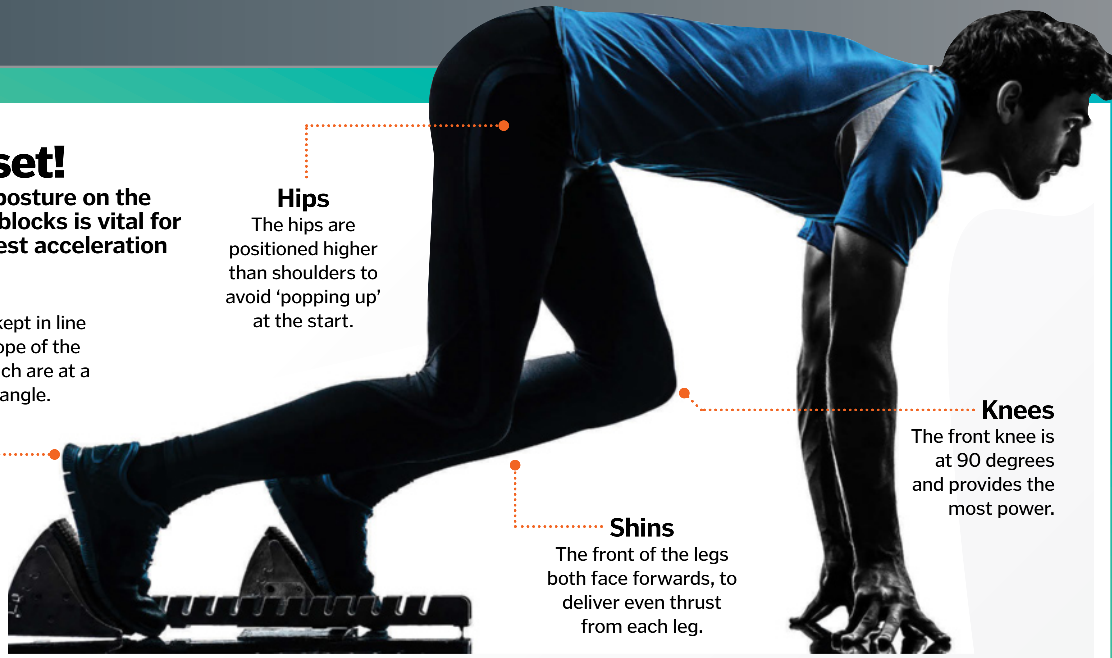
"A honeycomb grid flexes slightly underfoot and subtly boosts every stride"

On the starting blocks

When the starting pistol fires, the amount of force the sprinter can deliver for the first stride exceeds their friction with the track. Without starting blocks, their feet would simply slip backwards. Starting blocks also allow the body to be positioned at the perfect angle for the most efficient takeoff. A slight stretch of the Achilles tendon at the back of the lower leg primes the calf muscles for an explosive launch, and a downward facing posture makes it easier to take powerful strides during the crucial initial acceleration phase.

Get set!

Correct posture on the starting blocks is vital for the highest acceleration



Heels
These are kept in line with the slope of the blocks, which are at a 45-degree angle.

Hips
The hips are positioned higher than shoulders to avoid 'popping up' at the start.

Knees
The front knee is at 90 degrees and provides the most power.

Shins
The front of the legs both face forwards, to deliver even thrust from each leg.

Height advantage
Although being tall makes explosive starts harder, the middle of the race favours sprinters with the longest strides.

Temperature boost
Higher temperatures reduce the air density, which creates less wind resistance.

The finish
In the final few metres, the runners bend their arms back to minimise drag, and crane their head forward to cross the line first.

Peak speed
The maximum velocity for most sprinters occurs between 30 and 60m into the race.

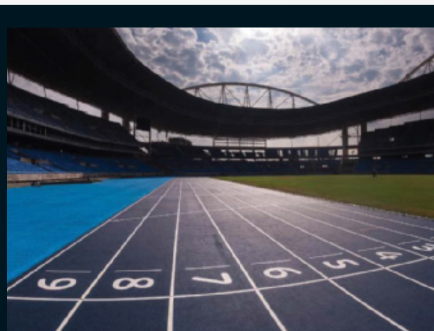
DID YOU KNOW?
92% of the energy Usain Bolt expends in a 100m race is used simply to overcome wind resistance!

Wind assist
A tailwind will give runners an advantage, but the maximum allowed for world records is 2m/s.

Heels up
The heels mustn't drop at the end of the stride, as this can cause a braking effect that wastes energy.

Rhapsody in blue

Like every Olympic track since 1976, the striking blue running track at Rio is made by Italian company Mondo. The synthetic rubber top layer provides a uniform non-slip texture, even when it is wet. The lower layer uses a honeycomb grid that flexes slightly underfoot and subtly boosts every stride. To cope with the higher temperature and humidity at Rio, the rubber compound has been reformulated, and the vulcanisation process that bonds the layers together tweaked, to ensure it will last throughout the competition and beyond.



Rio's royal blue track has been carefully designed for hot and humid conditions

The tallest bridge in the world

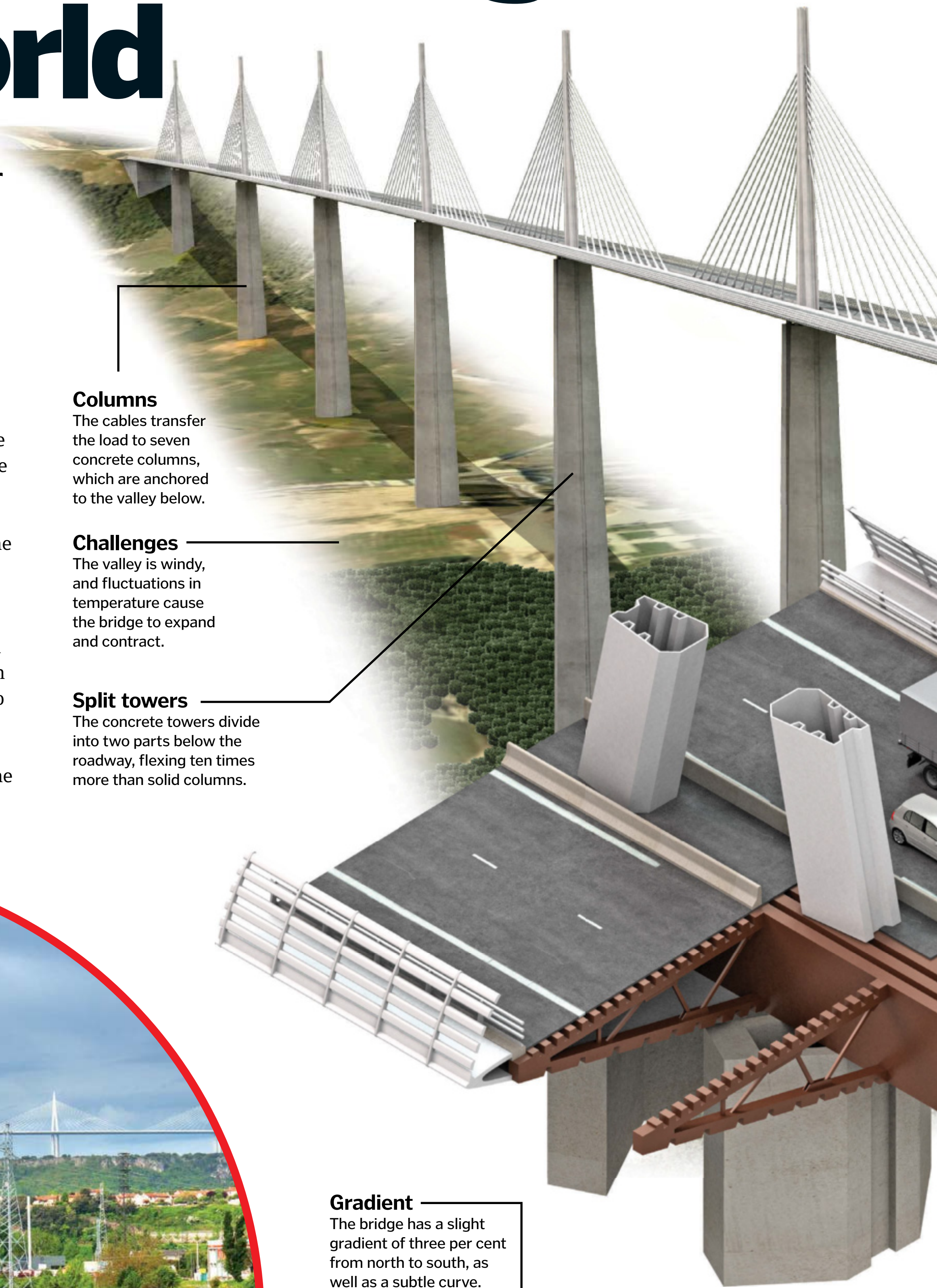
How do you build a permanent crossing over a vast, windy valley?

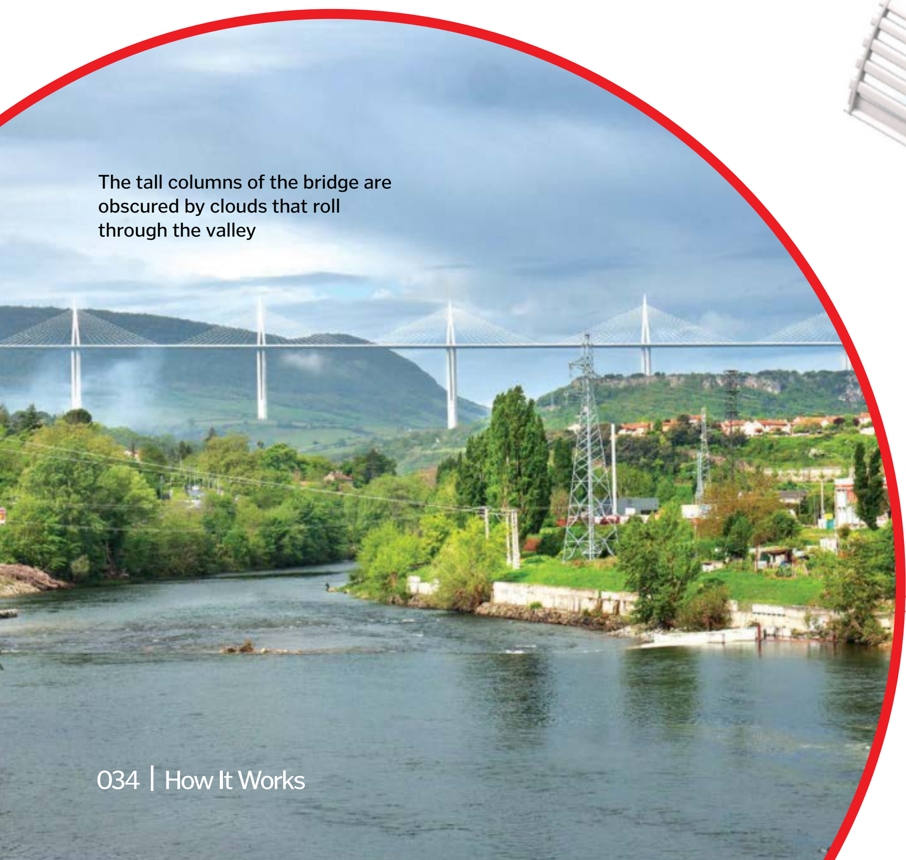
The Millau Viaduct in southern France is the tallest bridge in the world. It stretches over the vast River Tarn, reaching 2.46 kilometres across a valley. At the deepest part of the gorge, one mast stands 343 metres above the ground, which is taller than the Eiffel Tower.

Spanning this gap was no mean feat. Despite being built at one of the narrowest points of the valley, the bridge still supports the highest roadway in Europe, and must contend with strong wings and fluctuating temperatures. The structure flexes, expands and contracts, and it needs to be able to take the strain.

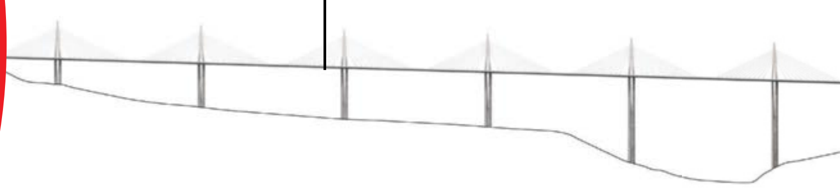
Millau Viaduct is an example of a cable-stayed bridge; it is supported entirely by seven columns that run from the concrete deck down into the valley below. The load is transferred to these columns by steel cables, anchored to pylons that stretch up above the road.

It stands so high that clouds form beneath the structure, giving the illusion that the bridge is hanging above the gorge.

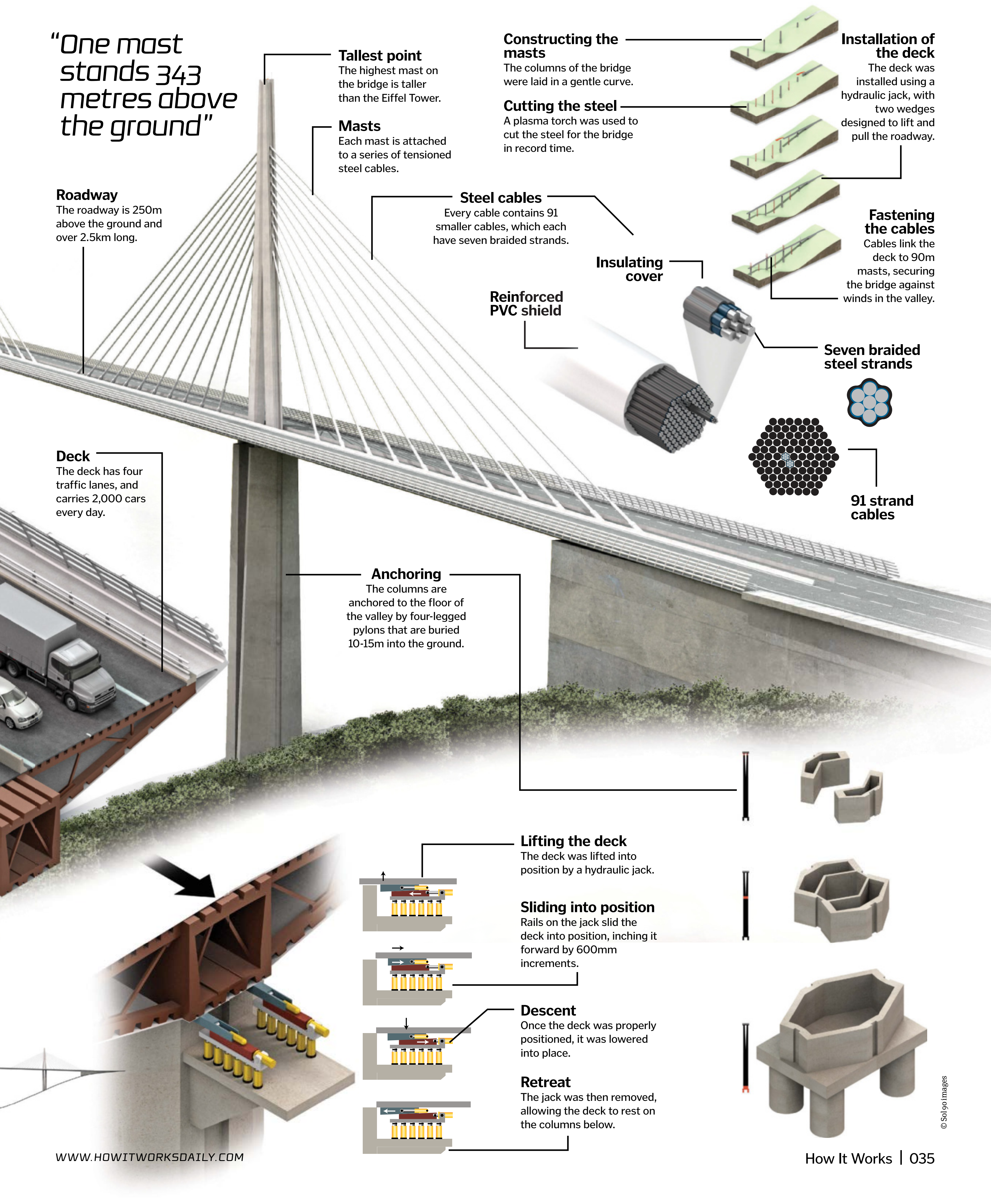




The tall columns of the bridge are obscured by clouds that roll through the valley



Gradient
The bridge has a slight gradient of three per cent from north to south, as well as a subtle curve.


"One mast stands 343 metres above the ground"
Tallest point
The highest mast on the bridge is taller than the Eiffel Tower.
Masts
Each mast is attached to a series of tensioned steel cables.
Constructing the masts
The columns of the bridge were laid in a gentle curve.
Cutting the steel
A plasma torch was used to cut the steel for the bridge in record time.
Installation of the deck
The deck was installed using a hydraulic jack, with two wedges designed to lift and pull the roadway.
Roadway
The roadway is 250m above the ground and over 2.5km long.
Steel cables
Every cable contains 91 smaller cables, which each have seven braided strands.
Fastening the cables
Cables link the deck to 90m masts, securing the bridge against winds in the valley.
Insulating cover
Reinforced PVC shield
Seven braided steel strands
91 strand cables
Deck
The deck has four traffic lanes, and carries 2,000 cars every day.
Anchoring
The columns are anchored to the floor of the valley by four-legged pylons that are buried 10-15m into the ground.
Lifting the deck
The deck was lifted into position by a hydraulic jack.
Sliding into position
Rails on the jack slid the deck into position, inching it forward by 600mm increments.
Descent
Once the deck was properly positioned, it was lowered into place.
Retreat
The jack was then removed, allowing the deck to rest on the columns below.

Catching counterfeiters

Bank notes have numerous security features that make fakes easier to spot

Bank of England notes have several security features to sort the genuine from the worthless. The cotton paper gives them a unique feel, and if you run your finger across the front, you'll notice raised print in certain areas. There's also metallic thread woven into every banknote.

Other features are a little harder to spot. Grab a magnifying glass and peer closely beneath the Queen's portrait – you'll discover micro-lettering showing the value of the note. Hold it up to the light, and a watermark of the Queen appears, and in ultraviolet light, a bright red and green number will be visible.

Both £5 and £10 notes have a hologram with the image of Britannia, while the £20 has a holographic strip showing Scottish philosopher Adam Smith. The £20 and the £50 also have a 'see through register'– if you hold the notes up to the light, lines on the back and front come together to form the pound sign.

The £50 note has an additional safety feature woven through it, called the motion thread. When tilted back and forth, the images move, and under UV light, the five blocks glow green. Notes from all over the world bear similar security measures to protect them against counterfeiting.

UV light can be used to check fluorescent features, to show whether or not notes are genuine

Treasure hunting with GPS

People are hiding secret stashes, and uploading their locations for others to find

Treasure hunts were once reserved for children and pirates, but in the modern world it has become a technological game. Geocaching is a global treasure hunt for anyone with access to a GPS device.

GPS works by locking on to three or more satellite signals, and calculating how long it takes for a signal to arrive from each. Using this information, it can pinpoint where you – and of course, the treasure – are located.

The cache varies from location to location, but typically includes a logbook, hidden inside a waterproof container, along with other little treasures. If you find the cache, you sign the logbook, and are free to take the treasure. In return, you are asked to leave something of equal or greater value.

The first geocache was left in a bucket in Oregon, US, in May of 2000. It contained books, software, and a childhood favourite – a slingshot. Today, there are more than 2.5 million caches across the world, ranging from traditional caches, to intricate puzzles.

There are rules around what to leave behind (nothing illegal or dangerous), but anyone can play. To join the hunt, sign up for a free account at Geocaching.com, search for a nearby cache, and input the co-ordinates into your GPS.

Geocaches come in all shapes and sizes, and are often hidden from view

WWF ADOPTION

© KLEIN & HUBERT / WWF

Snow leopards have survived in the Himalayas for thousands of years. But right now, there are as few as 300 left in Nepal. The harsh reality is that they're being hunted by poachers for their bones and precious fur – and they urgently need your help if they are to live on.

By adopting a snow leopard today, you'll help protect this endangered big cat for future generations.

Your present. Their future.
For as little as £3 a month, you or your loved one will receive an adoption pack, an adorable cuddly toy and regular updates from people on the ground working tirelessly to help save the beautiful snow leopard.

What's more, you'll have the satisfaction of knowing you're helping us to train and equip courageous anti-poaching rangers. And you'll discover what it takes – and how it feels – to help save a species.


a gorgeous snow leopard toy

+


an adoption pack

+


regular updates from the field

= *from just* £3 a month

Adopt a snow leopard today by filling in the form below, visiting wwfsnowleopard.com or calling 0845 200 2392

Yes, I would like to adopt a snow leopard today

Please indicate how much you would like to give each month

I would like to give ☐ £3 ☐ £5 ☐ £7 ☐ £10

My choice £ ☐ each month (min. £3)

Purchaser details

Title:__________ Initial:__________ Surname: ______________________

Address:______________________________________

______________________ Postcode: ______________

Tel no: ______________________ Date of birth: ______________

Email:* ______________________________________

*Please supply if you would like to receive emails from WWF (you can unsubscribe at any time)

Gift recipient details (if applicable)

☐ Tick this box if your adoption is a gift, then complete the details of the recipient below

Title:__________ Initial:__________ Surname: ______________________

Address:______________________________________

______________________ Postcode: ______________

Gift recipient's date of birth: ______________________

Would you like us to send the adoption pack directly to the recipient? ☐ Yes ☐ No

We'd like to keep you up to date with our projects and activities by post and telephone. If you'd prefer not to receive information in this way you can email us at supportercare@wwf.org.uk or call us on 01483 426333.

DIRECT DEBIT – WWF-UK

DIRECT Debit

Instruction to your Bank or Building Society to pay Direct Debits.

Service User Number 9 9 1 4 7 3

1. Name and full postal address of your Bank or Building Society Branch

To the manager of:______________________ Bank or Building Society

Address:______________________________________

______________________ Postcode: ______________

2. Name(s) of account holder(s)

3. Branch sort code ☐☐-☐☐-☐☐

4. Bank or Building Society account number ☐☐☐☐☐☐☐☐

5. WWF-UK Reference Number (Office use only)

6. Instructions to your Bank or Building Society

Please pay WWF- UK Direct Debits from the account detailed on the instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with WWF-UK and, if so, details will be passed electronically to my Bank/Building Society. Banks and Building Societies may not accept Direct Debit Instruction for some types of account.

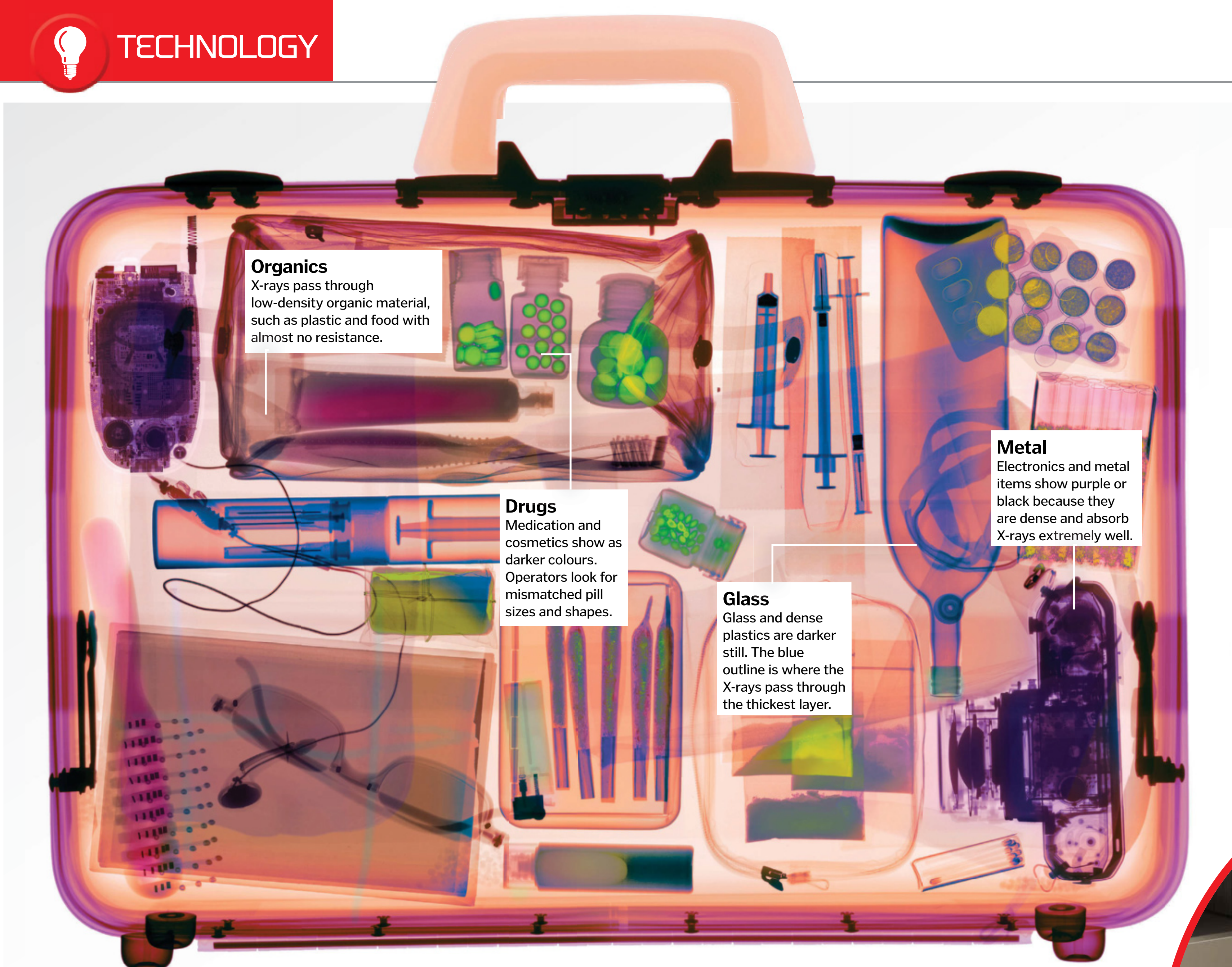
Signature(s): Date:

Your money will support our work to help save the snow leopard as well as other vital conservation projects.

Freepost RTSK-ZCLS-EEUZ, WWF-UK, York House, Wetherby Road, Long Marston, York, YO26 7NH

FRSB give with confidence

 AQH001192



Airport security

What happens to your luggage when it passes through the scanner?

The scanner that checks your hand luggage provides security staff with an instant view of the contents, automatically colour-coded according to the material each item is made from. It works by shining an X-ray beam through the bag from two directions. As each beam strikes your luggage, some of the X-ray energy is absorbed or scattered by the contents. The X-rays hit a detector on the other side, which makes an initial measurement of their position and energy. The beam then passes through a filter that absorbs low-energy X-rays, but allows high-energy X-rays to pass through and strike a second detector. This helps to reveal low-density items that don't absorb X-rays well.

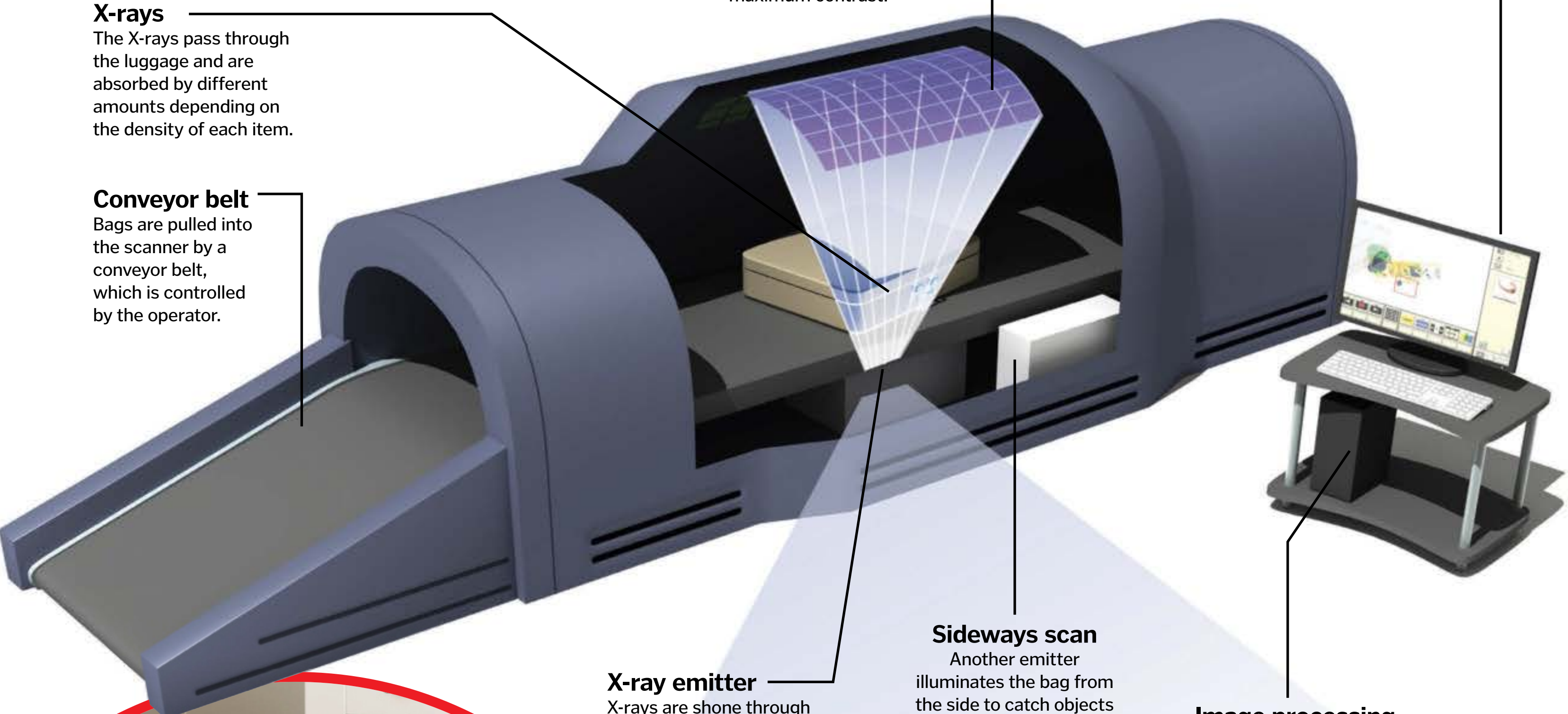
Computer algorithms use the pattern of X-ray absorption to determine the effective atomic mass of the material being scanned, as well as its density. Cross-referencing these values against a database of known substances allows the scanner to tell the difference between face cream and a plastic explosive, or cocaine and sugar, for example. Image-processing software then colours each item in the scan according to its material, and highlights any likely threats. To keep operators alert and focused, the software will occasionally insert a fake digital image of a suspicious item to check it is identified correctly.

Check-in baggage has to be scanned as well, and the automated X-ray machines used at UK airports can handle 1,800 bags an hour. If one of these spots something suspicious, it is automatically rechecked by a more sophisticated scanner that takes virtual slices all the way through the bag, like a hospital CT scan. This takes 16 seconds per bag and if the results from this are still flagged as a threat, a human operator will review the results of both scans, and determine if the bag needs to be opened.


145,000 bags pass through Heathrow airport every day, and they are all scanned

Inside a baggage scanner

How invisible X-rays can create a coloured image of your luggage



X-rays
The X-rays pass through the luggage and are absorbed by different amounts depending on the density of each item.

Conveyor belt
Bags are pulled into the scanner by a conveyor belt, which is controlled by the operator.

Detector
The X-rays that make it through are detected by a two-pass filter, which provides maximum contrast.

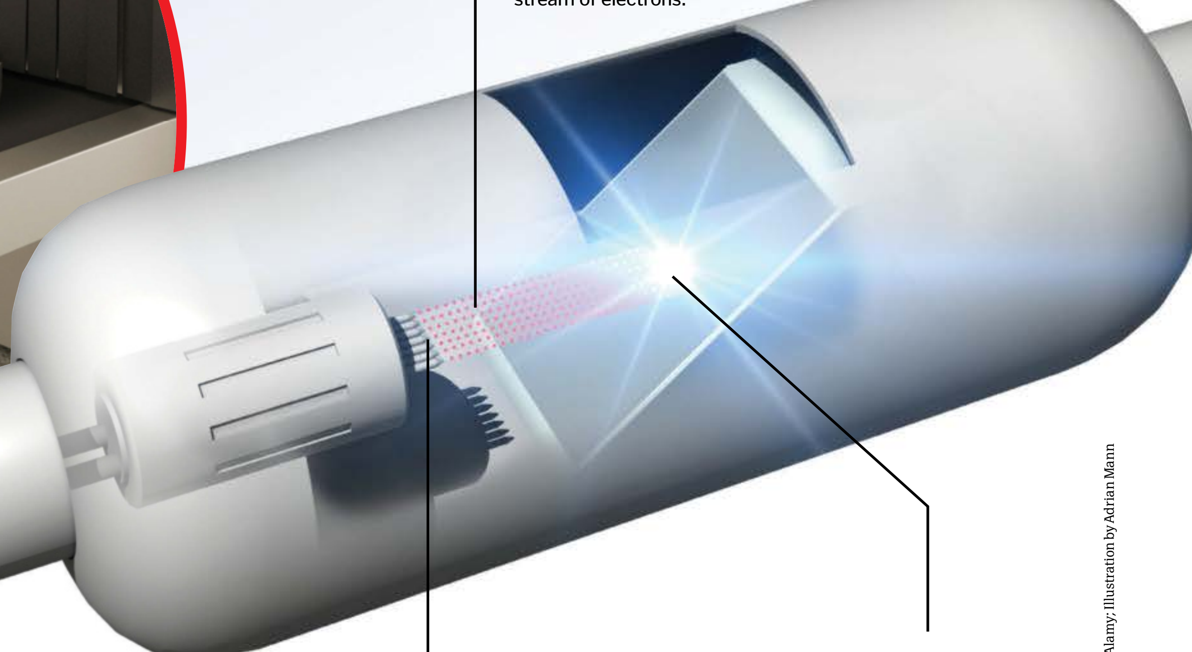
Display
The operator can pause the display and enlarge or enhance the image.

X-ray emitter
X-rays are shone through each bag by an X-ray tube under the belt.

Sideways scan
Another emitter illuminates the bag from the side to catch objects that may be hidden.

Image processing
Computer algorithms colour the image so that less dense materials appear in lighter colours.

Modern airport scanners can penetrate 2cm of steel and spot wires as thin as 0.1mm



Thermionic emission
The hot metal filament emits a stream of electrons.

Filament
An electric current heats a wire until it glows like a light-bulb filament.

Metal plate
When the high-speed electrons strike a metal plate, the collisions generate X-rays.

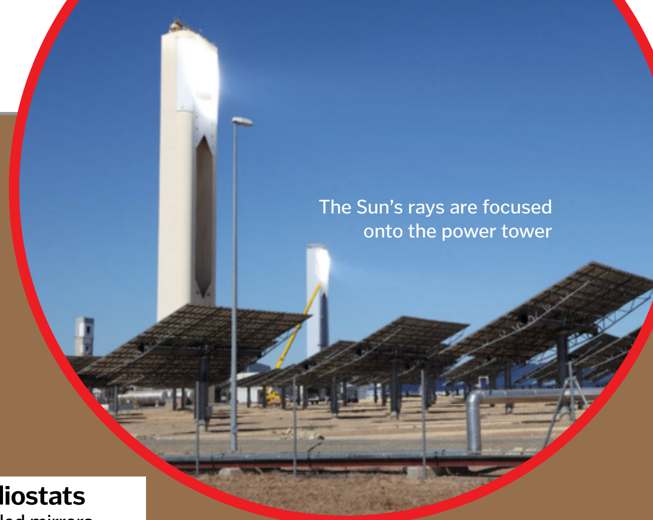
Harnessing the Sun

How vast solar power towers generate electricity

When light hits a solar panel, it generates an electrical current by nudging electrons away from their atoms, but solar power towers are different. These harness the heat of the Sun.

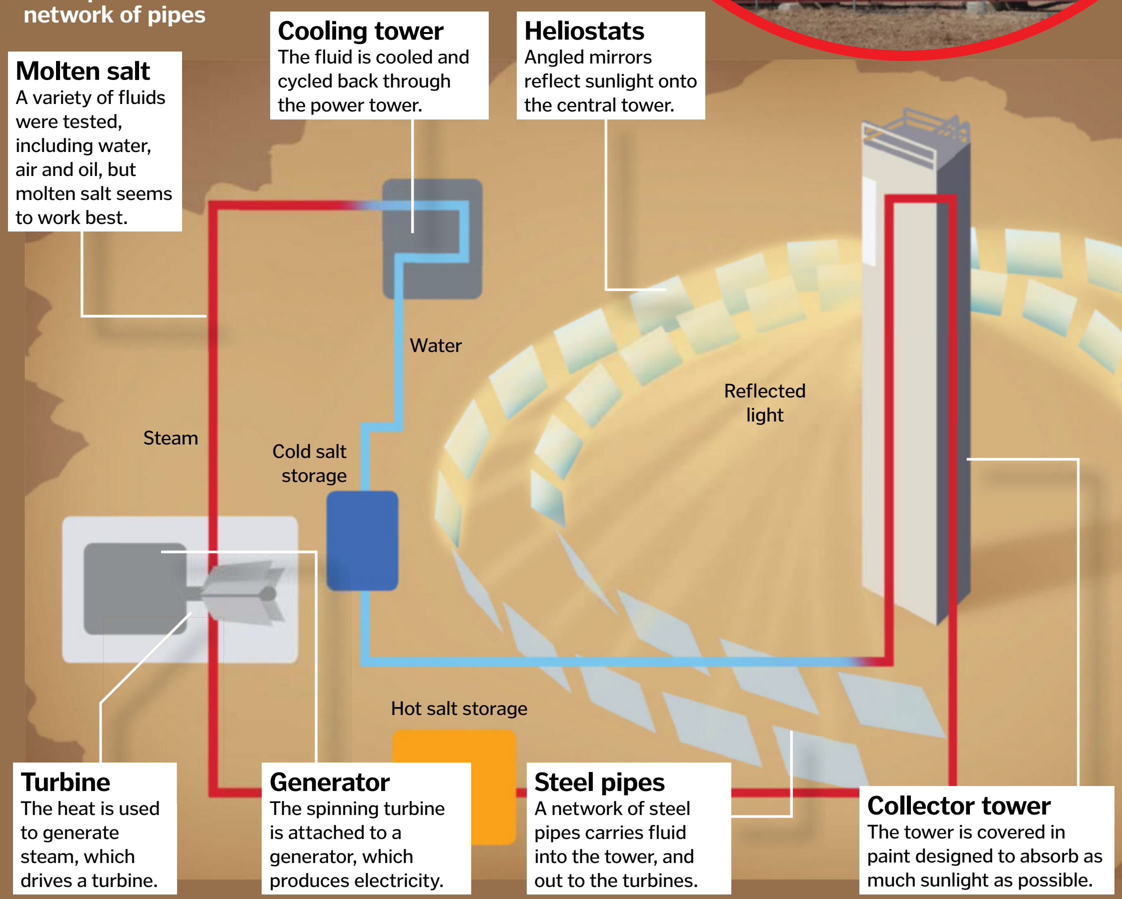
Power towers sit at the centre of rings of angled mirrors, or 'heliostats', which track the Sun as it passes across the sky. They reflect the light, focusing it all onto the tower. Inside, fluid (originally water, but now more often molten nitrate salt), heats up under the intense light. The heated liquid is used to generate steam, which in turn is used to drive a turbine.

This ingenious way of collecting solar energy allows heat to be stored even when the Sun goes down, providing a supply of electricity that can be used overnight and on cloudy days. Solar power towers aren't without their problems, though. The mirrors concentrate the Sun's energy to such intensities that wildlife entering the ring is in serious danger. Crescent Dunes Solar Energy Project in Nevada reportedly vaporised over 100 birds in just six hours. However, when compared to the environmental damage caused by coal-fired power plants, these towers still come out on top.


The Sun's rays are focused onto the power tower

Inside a power tower

The key to harnessing the Sun's power lies inside a network of pipes



Shrink-wrap seals

How does plastic cling so tightly to products?

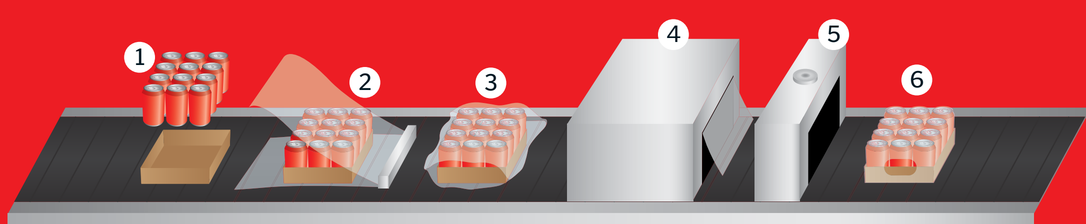
Shrink-wrap contracts when heat is applied, forming a secure seal around food products as they travel to and from our supermarkets. The secret behind the stick is polymers – long molecules made up of smaller units joined together. Before the wrap has been shrunk, these molecules are stretched out, forming neat, parallel bundles. When heat is applied, they curl up, knotting together and shrinking down by up to 50 per cent.

The most common material for shrink-wrap used to be polyvinyl chloride (PVC), but it is quite sensitive to changes in temperature. When it gets hot, it hardens. The newer plastic, polyolefin, is much more stable. Shrink-wrapping machines coat products in plastic, before running them through a heated tunnel to shrink the covering down to size.


Shrink-wrap clings tightly to cans and bottles from factory to supermarket

The packaging process

Sealing food packets in plastic is surprisingly simple



1 Products Food products are transported on either boards or trays.

2 Wrapping The products are encased in plastic wrap, covering the top and bottom edges.

3 Sealing At this stage, the plastic is sealed, although it is still loose.

4 Shrink tunnel Inside the shrink tunnel, the plastic is heated and polymer chains curl up.

5 Cooling fan The plastic is then cooled by fans, which sets the chains into their new positions.

6 Finished product The shrunken plastic fits snugly around the product, ready for shipping.

This cement kiln is fuelled by burning old car tyres

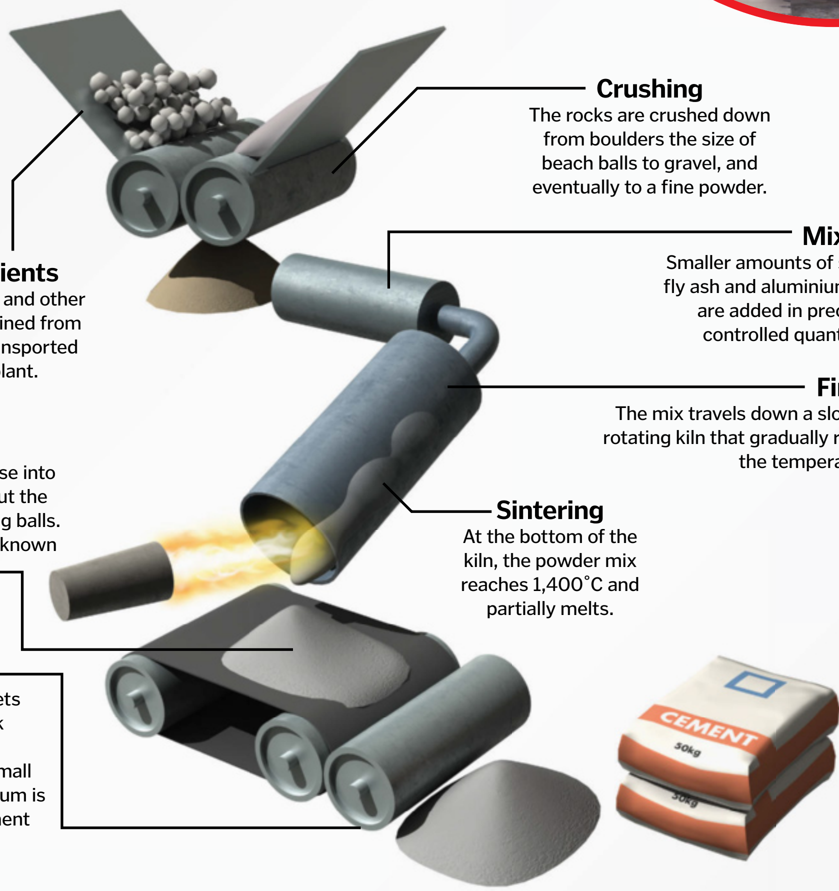
The difference between concrete and cement

CEMENT

This ancient technology provides the foundations of modern civilisation

Cement is made from a mixture of calcium, silicon, aluminium and other ingredients, which are heated and ground into a fine powder. When this mixture is combined with water, it forms a complex, interlocking crystal structure that is incredibly strong. In other words, cement hardens by reacting with water, rather than by drying out in the air as many other binding materials do. This means that it will even set underwater!

Cement was first used by the Ancient Macedonians and, three centuries later, by the Romans. Their recipe used limestone, with volcanic ash from Mount Vesuvius to provide the crucial silica and aluminium minerals. Modern cement uses clay instead of volcanic ash, but fly ash from coal-fired power stations is also added. The most widely used kind is called Portland cement because it has the same colour as Portland stone from Dorset, UK. The exact recipe for Portland cement was worked out by trial and error in the 19th century but the precise chemical reactions are still not fully understood.



Raw ingredients
Limestone, clay and other materials are mined from quarries and transported to the cement plant.

Crushing
The rocks are crushed down from boulders the size of beach balls to gravel, and eventually to a fine powder.

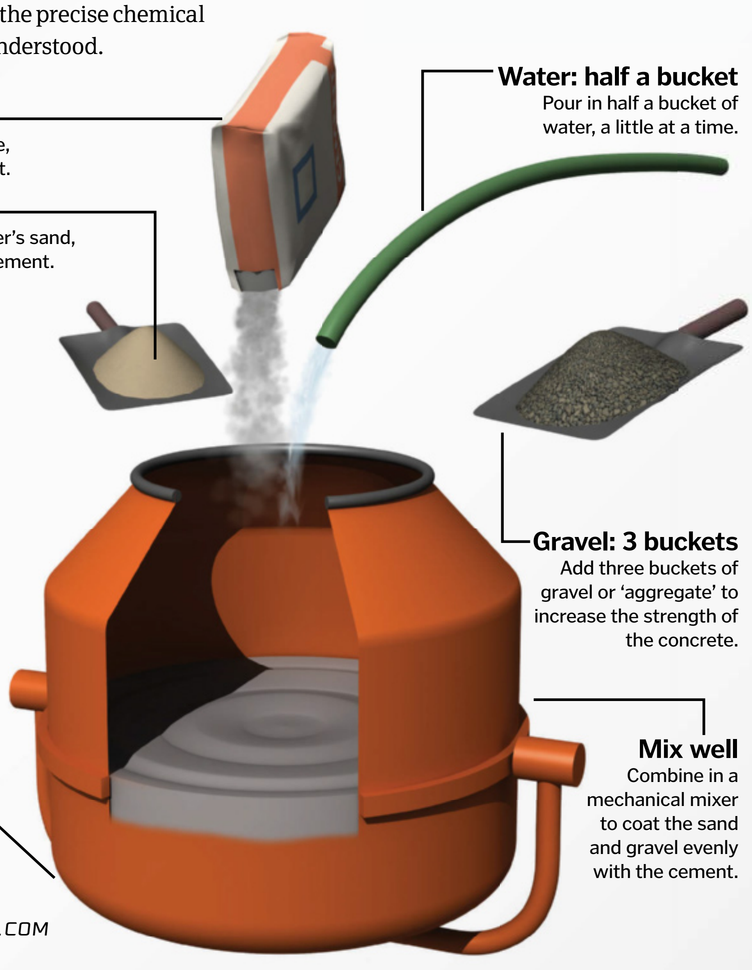
Mixing
Smaller amounts of sand, fly ash and aluminium ore are added in precisely controlled quantities.

Firing
The mix travels down a sloping, rotating kiln that gradually raises the temperature.

Sintering
At the bottom of the kiln, the powder mix reaches 1,400˚C and partially melts.

Clinker
The powders fuse into dark lumps about the size of ping-pong balls. This material is known as clinker.

Grinding
The clinker pellets are ground back down to a fine powder and a small amount of gypsum is added. The cement is then bagged.



Cement: 1 bucket
To make a high strength concrete, start with a bucket of dry cement.

Sand: 3 buckets
Add two buckets of 'sharp' builder's sand, with rough grains that grip the cement.

Water: half a bucket
Pour in half a bucket of water, a little at a time.

Gravel: 3 buckets
Add three buckets of gravel or 'aggregate' to increase the strength of the concrete.

Mix well
Combine in a mechanical mixer to coat the sand and gravel evenly with the cement.

Test
The concrete mix should be only just wet enough to be workable. Too much water weakens the mix.

Steel reinforcing bars or 'rebar' are usually embedded in concrete to make it even stronger

CONCRETE

Powdered cement can be turned into super-sturdy concrete with just a few added ingredients

Concrete is stone, sand and gravel held together by a key ingredient: cement. The stones in the concrete are stronger than the cement itself, so this is a way of transforming the mixture into a durable building material.

The chemical reaction that hardens the cement only requires about one part water for every five parts cement, by volume. However, a concrete mix this dry would be unworkably stiff and would leave air gaps that would weaken the structure overall. This is the reason why concrete is normally made with one part water for every two parts cement.

Modern high-performance concrete also has 'silica fume' added to it. This is an incredibly fine silicon dioxide powder, which is a by-product of industrial silicon production. The huge surface area of the tiny silica particles traps the water within the concrete and helps prevent cracking.

How do keys open doors?

Putting something under lock and key is really all about pattern-matching

Unlock the secrets of how these simple devices keep your possessions safe

Throughout history, numerous lock-and-key combinations have been used to keep rooms and valuables secure. The earliest lock comprised of a series of wooden pins that could be moved only by a key with a matching profile. Called a pin-lock, it formed the basis of today's pin-tumbler lock (often called a Yale or radial lock).

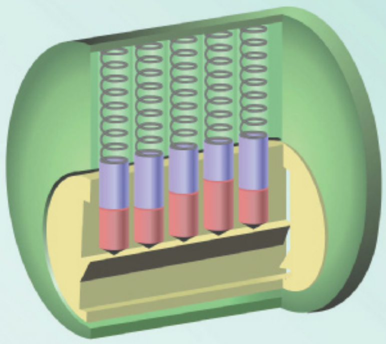
Inside the barrel of a pin-tumbler lock is a series of spring-loaded, two-part pins of varying length. When a small, flat-sided key is inserted into the barrel, the serrations along its edge push the pins up. If the key is the correct one for the lock, the pins will line up so that the bottom half of the pins sit perfectly inside the barrel. This enables the barrel to be turned (or tumbled) with the key, which opens the lock. Other keys may fit into the lock, but the lack of pin-alignment stops the barrel from turning.

Not all keys are flat, though. Those that fit into warded locks – used widely during the Middle Ages – are cylindrical. Instead of pins, these locks use curved plates, or wards, to block incorrect keys from turning. Only those with matching 'notches' can rotate fully. This design led to the first skeleton keys – versions that had most of their notches filed down to avoid the wards.

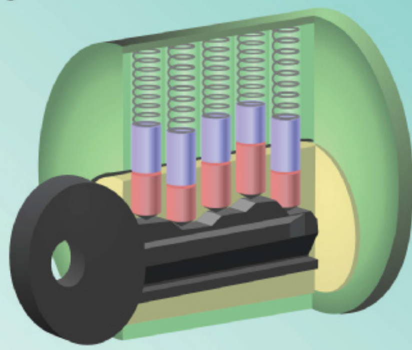
Many companies are now developing mechanical door locks that don't need physical keys. They can be opened with the sound of your voice or a swipe of your smartphone – although most still allow you to use an old-fashioned key.

How keys work

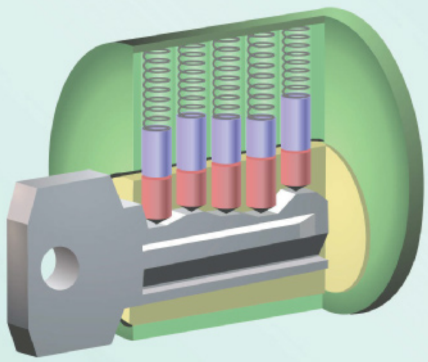
Take a look inside a pin-tumbler lock to understand how keys open doors



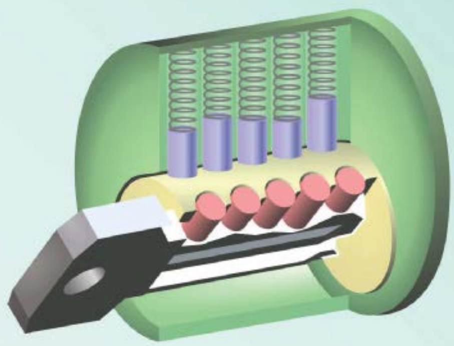
1 Springs and pins
A series of spring-loaded pins sit inside every cylindrical lock barrel. While the total length of each pin remains the same, the length of the separate sections of the pin (shown in purple and red) varies.



2 If it doesn't fit...
When a flat-sided key is inserted into a lock, its bumpy edge pushes the pins to different heights. When it's the wrong key, there is no alignment between the red sections of the pins.



3 Line them up
When the correct key is inserted into the lock, it pushes the pins up so that the break in the pins (where the red and purple sections meet) aligns exactly with the top of the gold-coloured barrel.



4 Open sesame!
Because the pins are in two parts, this alignment means that only the red sections sit within the barrel, which enables the barrel to turn, or tumble, opening the lock in the process.

The end of lost keys?

Tile tags act like homing beacons to help you track down missing valuables

A British insurance company estimated that the average person spends 3,680 hours – that's 153 days – searching for misplaced items, mainly smartphones and keys. However, a gadget called Tile can dramatically reduce these wasted hours, helping you find your essential items quickly and easily. While it looks like a simple square of plastic, each Tile contains a Bluetooth tracking device. If you attach it to your valuables, it can transmit its location – in the form of radio waves – over short distances (around 30 metres), using very little power.

Almost all smartphones have in-built Bluetooth, so by installing a dedicated app, they can wirelessly communicate with your Tiles. If you lose your keys, the app directs you to their location using sound. If you misplace your phone, you can ring it by pushing a button on one of your Tiles. It will play a tune even if it's on silent!

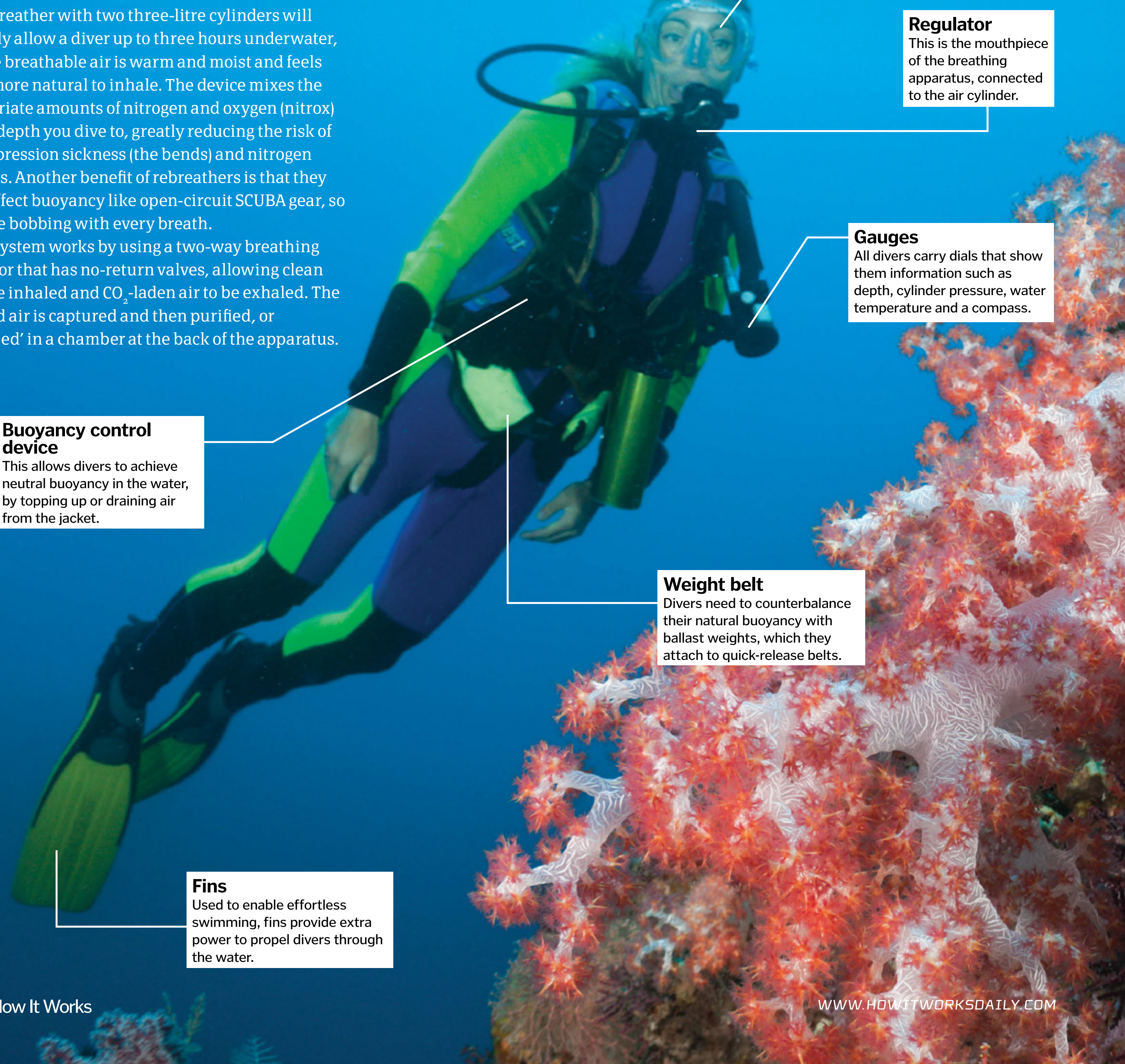
How rebreathers work

Divers can be at one with the ocean by recycling the air they exhale

A rebreather is a SCUBA device that recycles your breath over and over again. This closed-circuit system differs from conventional SCUBA gear, which supplies you with fresh air from a tank and releases your exhaled air into the water as bubbles. Rebreathers make it possible to dive much deeper, for much longer, and enable you to experience more in the water because they are almost totally silent. This makes them ideal for those who are after up-close animal encounters as they enable you to be a silent by-swimmer and not a noisy bubble blower.

A rebreather with two three-litre cylinders will typically allow a diver up to three hours underwater, and the breathable air is warm and moist and feels much more natural to inhale. The device mixes the appropriate amounts of nitrogen and oxygen (nitrox) for the depth you dive to, greatly reducing the risk of decompression sickness (the bends) and nitrogen narcosis. Another benefit of rebreathers is that they don't affect buoyancy like open-circuit SCUBA gear, so no more bobbing with every breath.

The system works by using a two-way breathing regulator that has no-return valves, allowing clean air to be inhaled and CO_2-laden air to be exhaled. The exhaled air is captured and then purified, or 'scrubbed' in a chamber at the back of the apparatus. The CO_2 is removed by passing the gas through granules of soda lime – a mixture of calcium hydroxide and other chemicals. The scrubbed gas then goes into a mixing chamber where sensors check the partial pressure of oxygen (PO_2) and top it up from valves attached to the two tanks. This is because the PO_2 will periodically fall as the diver's body metabolises oxygen, or if they ascend. The other tank is full of inert 'diluent' gas, which is also added to keep the oxygen pressure at a safe and constant level as the diver descends. The air is then ready to be inhaled once more!



Mask
The mask protects the diver's face and creates an air pocket to allow them to see perfectly underwater.

Regulator
This is the mouthpiece of the breathing apparatus, connected to the air cylinder.

Gauges
All divers carry dials that show them information such as depth, cylinder pressure, water temperature and a compass.

Buoyancy control device
This allows divers to achieve neutral buoyancy in the water, by topping up or draining air from the jacket.

Weight belt
Divers need to counterbalance their natural buoyancy with ballast weights, which they attach to quick-release belts.

Fins
Used to enable effortless swimming, fins provide extra power to propel divers through the water.

"Rebreathers enable you to be a silent by-swimmer and not a noisy bubble blower"

Divers in the 1800s used a heavy metal helmet and a manual pump from the surface to breathe underwater

A history of humans underwater

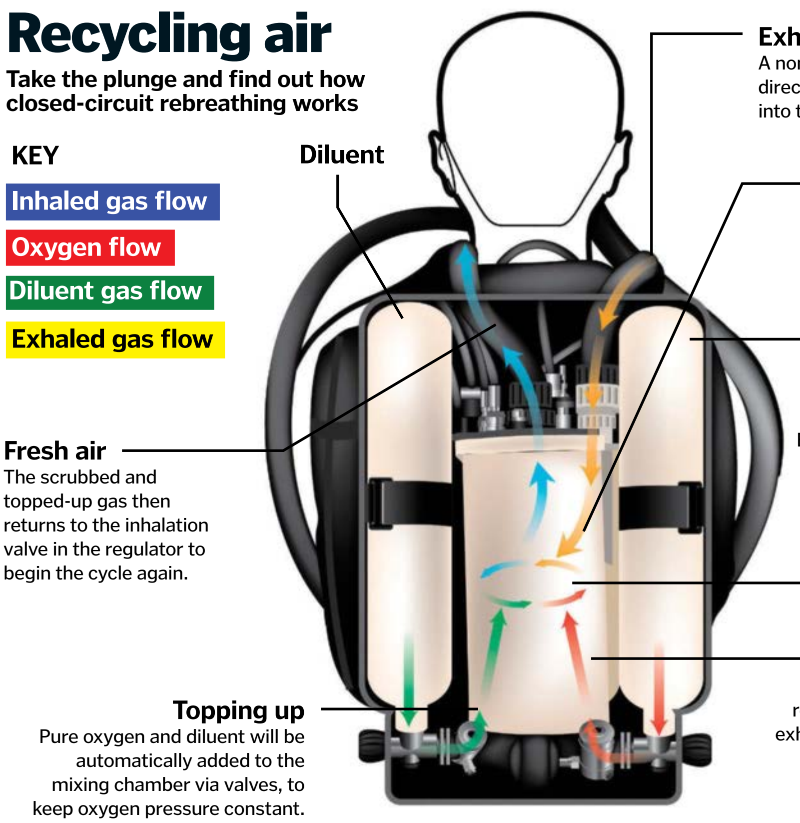
Ocean exploration has fascinated humans for thousands of years. There are a huge number of recorded instances of primitive underwater breathing apparatus, from sponges, to inflated goatskins, to long, snorkel-like reeds.

It wasn't until the 16th century when underwater exploration took a leap forward with the use of diving bells, and soon afterwards, full diving suits were developed. The suits were furnished with long pipes, through which air was pumped manually from the surface. They allowed divers to reach around 18 metres in depth initially, and then with the development of better materials to withstand water pressure, the depths increased.

SCUBA gear as we know it today was pioneered in the 1800s as inventors strove to develop a way to keep air pressurised and breathable. The word SCUBA was first used in 1939, and then Jacques Cousteau paved the way for modern SCUBA gear with his Aqua-Lung in 1943.

Recycling air

Take the plunge and find out how closed-circuit rebreathing works



Exhaled breath
A non-return valve directs the exhaled air into the closed circuit.

Mixing chamber
The scrubbed gas then enters a chamber where oxygen sensors measure its partial pressure of oxygen.

Scrubber unit
Exhaled air travels over the right shoulder and reaches the scrubber unit.

Scrubbed air
The scrubber unit removes CO_2 from the exhaled air by filtering it through soda lime.

Topping up
Pure oxygen and diluent will be automatically added to the mixing chamber via valves, to keep oxygen pressure constant.

Fresh air
The scrubbed and topped-up gas then returns to the inhalation valve in the regulator to begin the cycle again.

Hammer time

Get to grips with the different types of hammer and their uses for your home

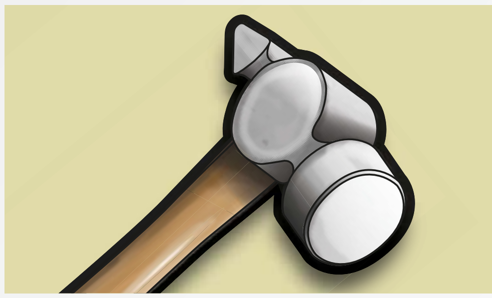
A hammer transfers kinetic energy to its target instantly

A hammer is a large mass on the end of a lever. When you swing the hammer, the handle extends the effective length of your arm, so that the end of the hammer sweeps a larger arc. This means there is more time for your arm muscles to accelerate it. When the hammer strikes the nail it is travelling fast and because the head is very hard, it doesn't absorb the blow. This means the kinetic energy is instantly transferred to the nail. The resultant force is large enough to overcome the friction of the material you're driving the nail in to.

There are dozens of different designs of hammer depending on the task at hand. Learn about some of the different types here, so you can nail your next DIY job.

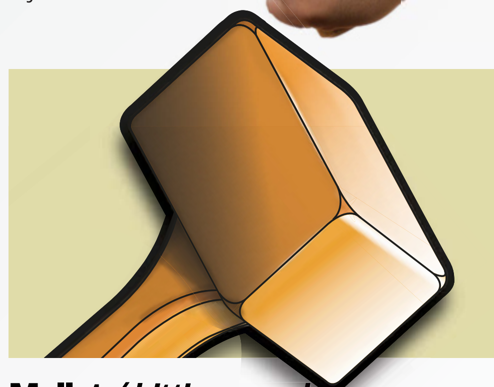
Claw hammer / *driving nails*

The head is flat to provide a large striking area, so that it is harder to miss the nail. The curved fork works as a lever to prise nails out of wood when required.



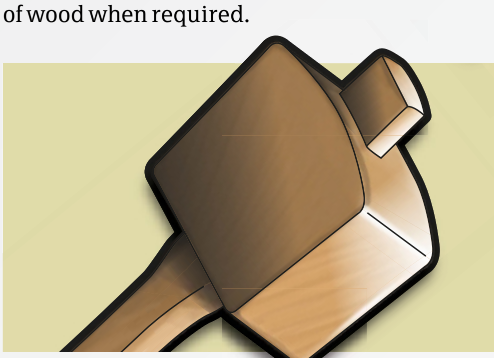
Ball-pein / *metal-working*

A rounded head is used for hardening metal and flattening rivets – permanent mechanical fasteners that join pieces of metal. The hammer pounds each rivet into a mushroom shape.



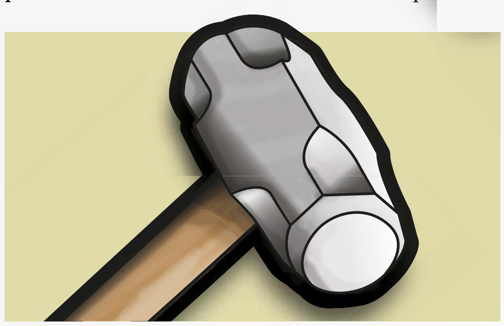
Mallet / *hitting wood*

Mallets are made of relatively soft wood and have a very wide face. This spreads the force of the blow and avoids denting the work piece like a metal hammer would.



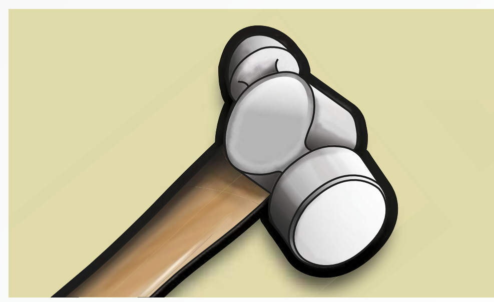
Dead blow hammer / *precision*

The head of the hammer has a cavity partly filled with fine steel shot. This spreads the force of each blow over a longer period of time, which helps eliminate any bounce.



Sledgehammer / *demolition*

Taking their name from the Old Norse word meaning a blow or strike, sledgehammers use the heaviest head and the longest handle, to deliver the maximum force.

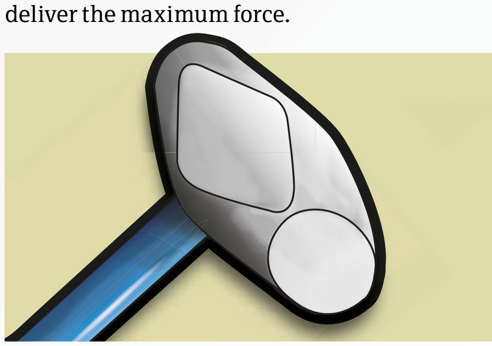


Jewellery hammer / *shaping*

This small and lightweight hammer has a large, flat head for beating gold and silver flat or for striking chisels. The rounded end can be used for riveting.

Geological hammer / *splitting*

Like a miniature pickaxe, this hammer is used to break off rock samples and to split them open to reveal fossils inside. The flat face can trim off jutting lumps.



Brass hammer / *oil pipelines*

Brass is a softer metal that is sometimes used to avoid deforming steel surfaces. But it is also useful because it doesn't create sparks, so it's safer around inflammable materials.

Cross-pein / *making cabinets*

The thin end allows you to tap precisely, making it easier to hammer in small pins and tacks for light carpentry. Larger cross-pein hammers are used for shaping metal.

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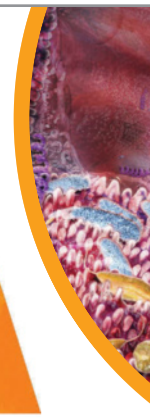


The good, the bad & the ugly BACTERIA

YOUR BODY IS HOME TO TRILLIONS OF MICROBES, AND YOU WOULDN'T SURVIVE WITHOUT THEM

It might surprise you to know that only around half the cells that make up your body are actually human. The average person has an estimated one-to-one ratio of human cells to microbes, the majority of which are bacteria. Known as the microbiome, your body's bacterial ecosystem has a huge influence on your health.

Bacteria often get a bad rap. Some of them cause infections, make you feel sick, and a few even appear to feast on your flesh. That said, these harmful germs are in the minority. Fewer than five per cent of microbes are known to cause disease in humans and the majority of bacteria that call your body home are harmless.

Many species, particularly those that reside in our digestive systems, are highly beneficial. Researchers are only just starting to discover the extent to which gut bacteria influence our health. The bacteria that colonise your intestines (known as gut flora) help break down some of the foods that you can't digest into nutrients that you can. They also produce some vitamins that your body can't synthesise on its own, including K2 (which helps blood clot properly) and B12 (involved in several key functions, including protein metabolism). The overwhelming presence of good bacteria in a healthy gut helps suppress the growth and survival of bad bacteria, protecting us from illness.

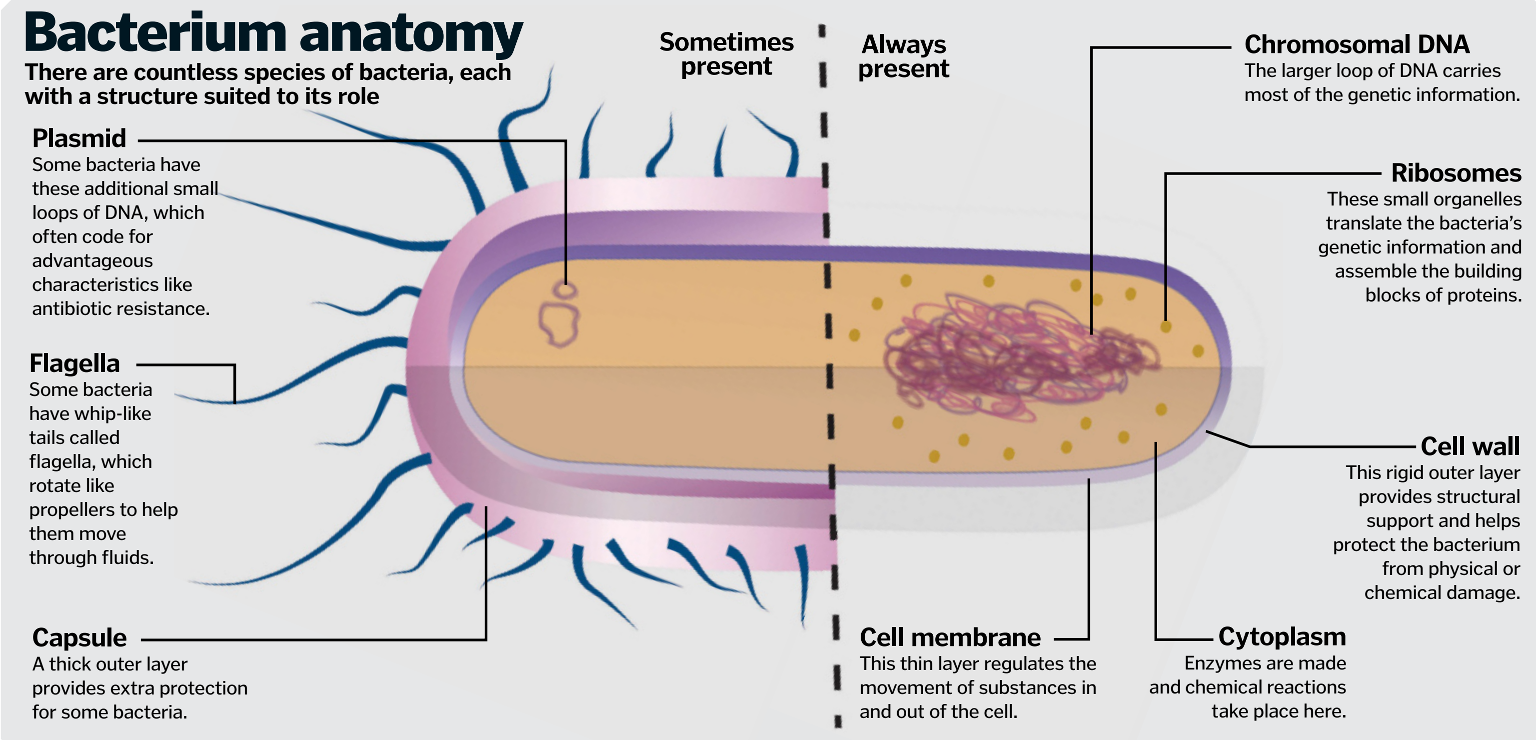
The role of your intestinal bacteria extends far beyond digestion. Studies have linked imbalances in gut flora to a range of conditions, including heart disease, diabetes, colic and Parkinson's. The health and diversity of your microbiome can influence how effective your immune system is, and can even affect your behaviour and mental health.

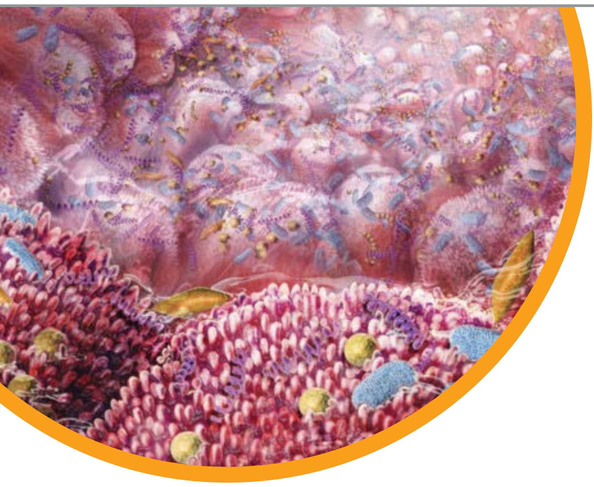
Research suggests that the combination of different bacteria in your gut is an important factor in whether or not you become obese or develop diabetes. The composition of your microbiome can change how you store fat, how you regulate blood glucose levels and how your body responds to the hormones that regulate appetite. Obese individuals tend to have a less diverse microbiome, whereas the gut flora of lean people includes a wide variety of bacterial species.

Although the majority of your body's bacteria resides in your intestines, your skin also plays host to a multitude of microbes. Your skin flora helps regulate inflammation, a process that helps the body heal but can be damaging if left unchecked. Research by the University of Oregon found that we are each surrounded by our own personal atmosphere of microbes. Your microbiome is unique like a fingerprint: it is even possible to identify someone from a sample of their bacterial 'cloud'.

Bacterium anatomy

There are countless species of bacteria, each with a structure suited to its role





Prebiotics vs probiotics

Diet is a very significant factor in the health of your gut flora. Both prebiotic and probiotic foods are beneficial to your microbiome, but what is the difference between the two?

Probiotic foods contain live bacteria that give your digestive system a helping hand. Foods that are made through fermentation – a process by which bacteria naturally present in the food start digesting its sugars – are rich in probiotics. This group includes yoghurt, sauerkraut, kimchi and some cheeses.

Prebiotic foods are high in certain kinds of fibre, which we are unable to digest, but are a valuable source of nutrition for the bacteria in our guts. While all prebiotics are fibres, not all fibres are prebiotic; many vegetables, legumes, grains and nuts are naturally high in the types of fibre that keep gut bacteria healthy.

"The majority of bacteria that call your body home are harmless"

Gut-friendly foods

Some of the snacks that help support your body's bacteria

Fermented cabbage
Probiotic
Turning cabbage into sauerkraut creates a sour snack packed full of microbiome-boosting Lactobacillus bacteria.

Fruits
Prebiotic
Fibres like inulin and pectin, found in certain fruits, improve the balance of good intestinal bacteria.

Yoghurts
Probiotic
Yoghurts marketed as containing live or active cultures are teeming with beneficial bacteria.

Leeks, onions, garlic
Prebiotic
Members of the allium family of vegetables are high in the fibre fructans.

Nuts and seeds
Prebiotic
Seeds like flax and chia are high in fibre. Hazelnut skins are a rich source of prebiotics too.

Legumes
Prebiotic
Foods like beans and lentils are high in fibres that encourage healthy gut bacteria to grow.

Fermented foods such as , kimchi and live yoghurt contain strains of good bacteria

Studies suggest that a diet full of junk food destroys around 30 per cent of your beneficial gut bacteria

Gut instinct

How bacteria control your mind

One of the most unexpected revelations of gut flora research has been the link between your microbiome and your state of mind. The gut-brain axis is a two-way communication pathway between the intestines and the brain. The enteric nervous system, also known as the 'second brain', is a complex network of neurons in the gut that can act independently.

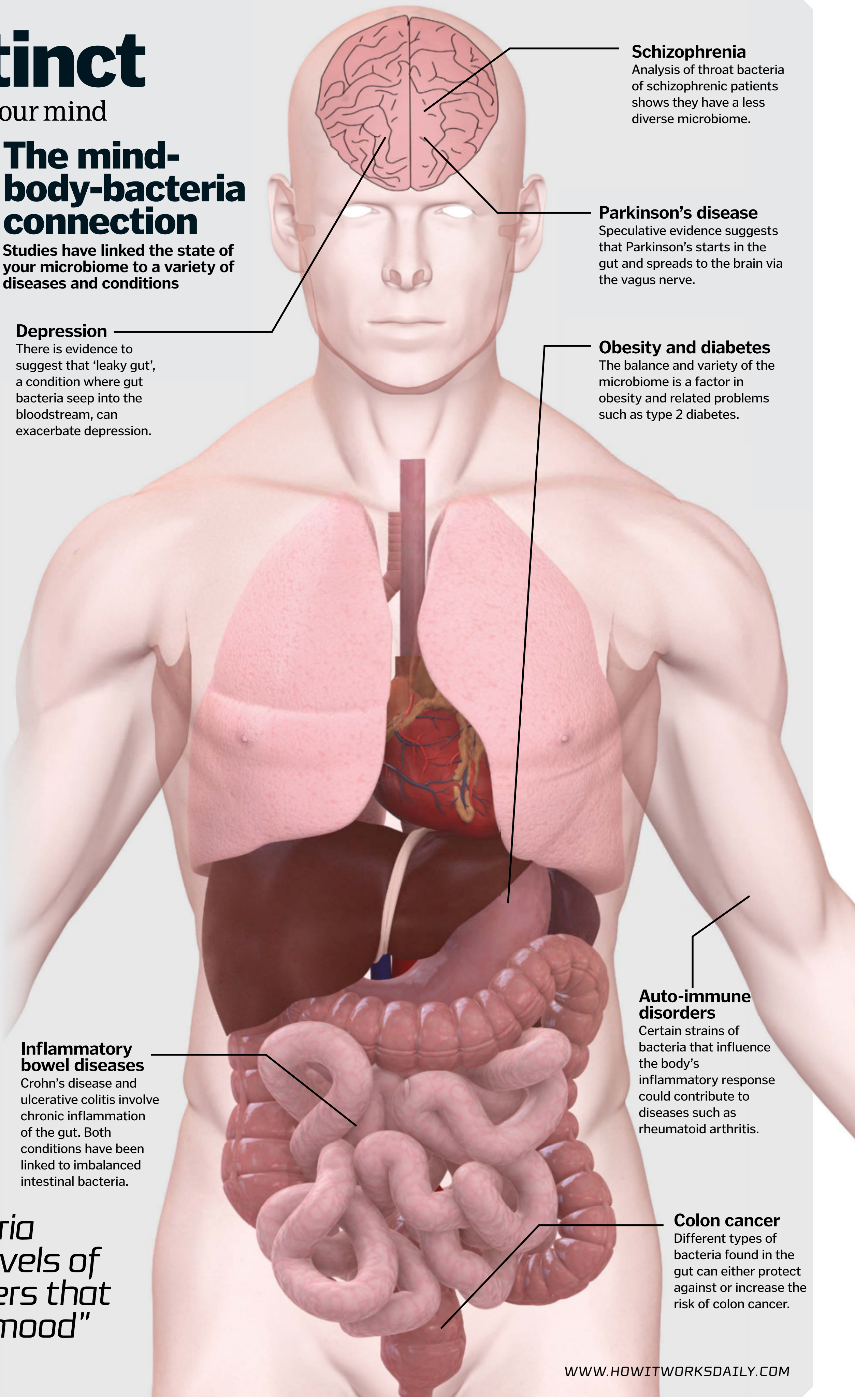
It is not yet clear exactly how your body's microbes influence the brain, but it is thought that several different mechanisms are at work. Gut bacteria have been found to produce high levels of neurotransmitters that regulate your mood, including 95 per cent of your serotonin and 50 per cent of your dopamine. Some bacteria can also activate the vagus nerve to communicate directly with the brain. In this way they can stimulate the production of other mood-regulating chemicals such as GABA. Low levels of each of these neurotransmitters have been linked to depression and anxiety, leading researchers to consider possible gut flora treatments.

In an effort to examine the importance of gut flora on behaviour, scientists have conducted various studies with mice. Germ-free mice are raised in sterile conditions to ensure they don't develop a microbiome. These rodents exhibit behaviours similar to what humans would describe as anxiety, depression, and even in some cases, autism. When scientists treated them with various strains of gut bacteria, it appeared to restore regular behaviour. While it is a huge step from mouse to human, these studies are promising. Researchers predict that a new generation of probiotic medicines, coined 'psychobiotics', could be used soon.

"Gut bacteria produce high levels of neurotransmitters that regulate your mood"

The mind-body-bacteria connection

Studies have linked the state of your microbiome to a variety of diseases and conditions



The bad and the ugly

The bacteria that are harmful to us can be devastating, if not deadly

Although only a small fraction of known bacterial species causes disease, they are capable of wreaking havoc on our bodies. Harmful bacteria can enter the body in several ways. For instance, we can inhale or ingest them, or they can enter through broken skin.

Once inside, they can reach their target site, such as the lungs or intestines, where they attach to our cells and multiply. Our bodies provide these bacteria with nutrients, but in return they release toxins, which can damage our tissues.

Our immune system provides some protection against these microscopic invaders. Immune cells can identify and destroy pathogens, but some bacteria have evolved methods of evading our internal defence mechanisms. It is in cases where these hardy germs persist that we need the help of antibiotics to eliminate infections before they spread.

Bacteria adapt to their environment so quickly that if any survive, they can develop immunity to these medications. The rise of antibiotic-resistant 'superbugs', which can cause life-threatening infections, is an increasingly serious threat to global health.

Antibiotic-resistant bacteria

These immune strains of bacteria could become killers

Bacteria evolve fast: they multiply rapidly and can even exchange advantageous genetic traits with one another by transferring plasmids. These abilities mean bacteria can adapt to changing environments quickly. Unfortunately for us, this means that even our most powerful antibiotics could soon be useless.

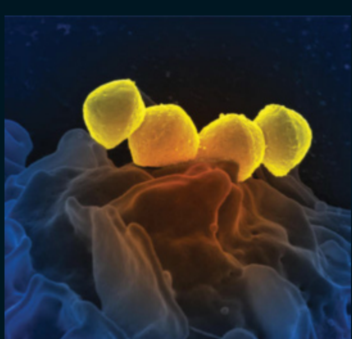
Over-use of antibiotics has led to many strains of pathogenic bacteria becoming immune to these medicines. A class of antibiotics known as polymyxins are seen as the last resort against bacteria. These substances should be able to destroy the superbugs that don't respond to any other kind of antibiotic – or at least, that was the idea.

Scientists across the world have reported finding several strains of bacteria that carry a gene which makes them resistant to colistin, a type of polymyxin. If resistant bacteria such as these become widespread, infections that were once cured easily with a single course of antibiotics could become deadly.

Over-prescription of antibiotics has exacerbated the problem of resistant bacteria

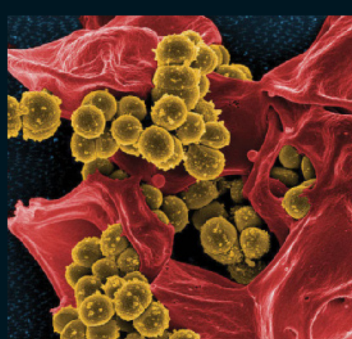
Deadly bacteria

The most dangerous bugs spread easily, cause devastating illness, resist antibiotics, or are a lethal combination of all three



Group A Streptococcus

Infections from this bug are usually mild, but in rare cases they cause necrotising fasciitis, or 'flesh-eating' infections. The bacteria infect body tissues and produce toxins that destroy them.



Staphylococcus aureus

Superbug strains of these bacteria, known as MRSA, spread easily by human contact and have been a serious problem in hospitals. They can cause deadly diseases such as pneumonia.

Escherichia coli

While most E. coli live harmlessly in the gut, some strains can cause food poisoning or more severe problems, and have developed resistance to many antibiotics.

Yersinia pestis

This bacterium was responsible for bubonic plague, or the Black Death, which caused millions of fatalities in the 14th century. Without treatment, it kills nearly 100 per cent of those infected.

MAKING CHEESE

Discover how this delicious dairy product is made, from milk to plate

1 Begin with milk
The milk is heated, and a culture is added to acidify the milk, turning lactose (a sugar) to lactic acid.

2 Coagulation station
A coagulant, such as rennet (naturally found in cows), is added to thicken the milk into curds (solid) and whey (liquid).

3 Curds and whey
The curd is cut and pressed to release whey. How it is cut defines the cheese – for instance, cheddar curds are stacked.

4 Moulding the cheese
The cut curds are sometimes heated and re-cut for the right consistency, before everything is placed in round moulds.

5 Salty essentials
Salt preserves the cheese and adds flavour. It's either added to the curds or incorporated by bathing the moulded cheese in brine.

6 Age to perfection
Cheese is aged in controlled environments. This forms the rind, and the ageing process determines the specific flavour and texture.

7 Differing methods
The ageing time varies for different cheeses. Fresh cheeses (like ricotta) are ready immediately, but ripened cheeses (like brie) mature for up to a month.

60 SECOND SCIENCE

Cell division

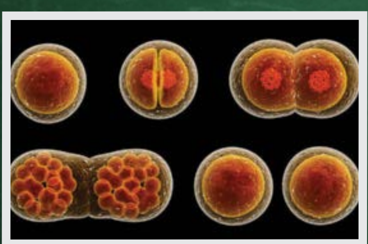
GET TO GRIPS WITH MITOSIS AND MEIOSIS

BACKGROUND

The human body starts out as just a single cell, but by the time we are fully grown, we are made up of more than 37 trillion. Every second, millions of these cells die, and millions more are made to take their place. The process by which this happens is called cell division: one cell divides to become two, two divide to become four, four divide to become eight, and so on. It all starts with replication of the DNA genetic code.

IN BRIEF

There are two types of cell division: mitosis and meiosis. The single cell that starts it contains 23 pairs of chromosomes, one set from each parent. These are made from DNA, which stores genetic instructions. Each time a cell wants to divide, it needs to replicate this genetic code, and both types of cell division begin with the same step. The single DNA molecule of each chromosome is duplicated, forming a near-perfect copy. If the cells are to be used for growth and repair, they will need a full set of instructions. Each new daughter cell receives two full sets of 23. This is mitosis. But if the cells are going on to form sperm or eggs, they only need one set. This is so that when a sperm fertilises an egg, the resulting embryo has two complete sets, not four. This is meiosis.



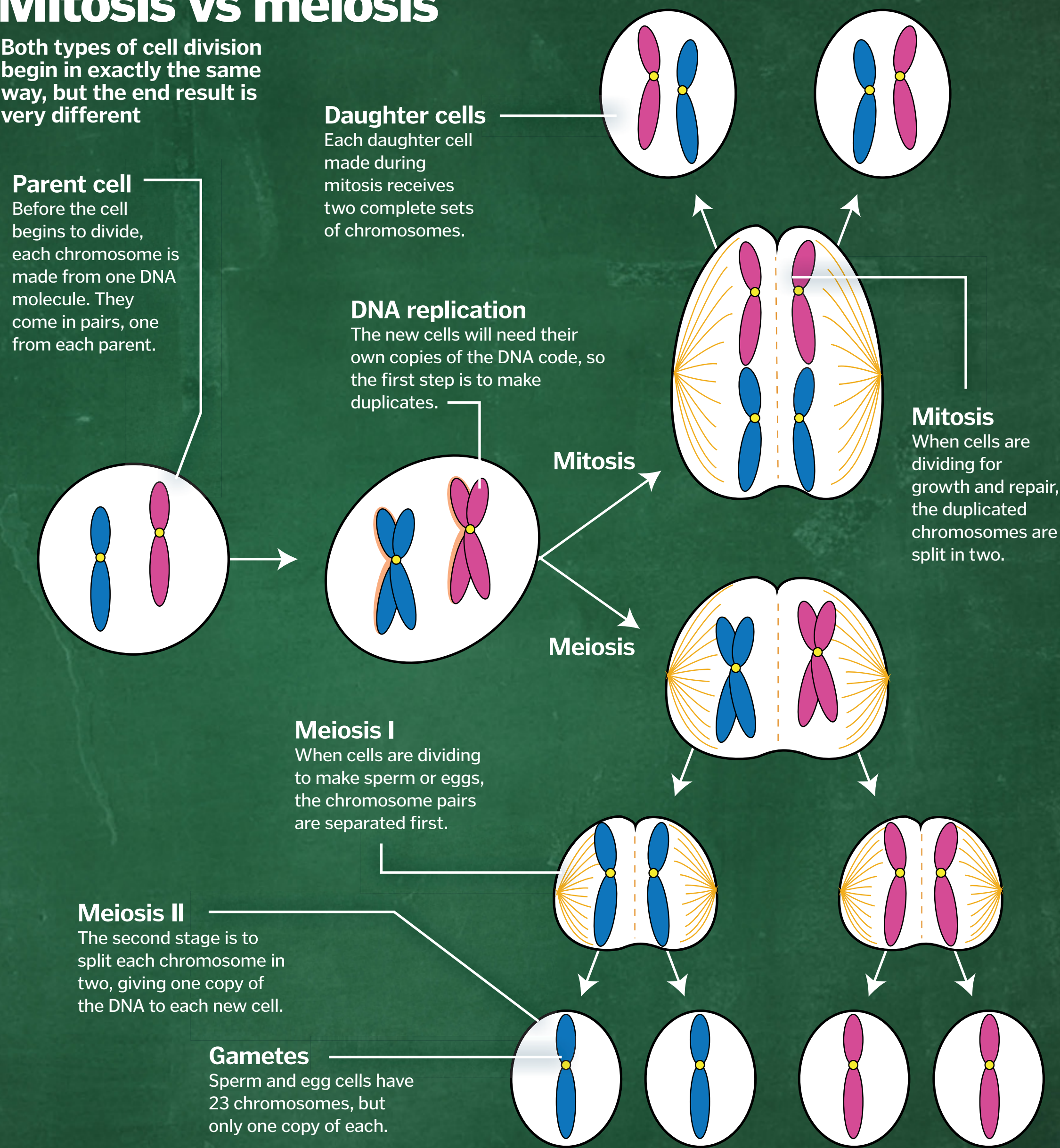
Cell division involves duplicating DNA and then dividing it between daughter cells

SUMMARY

There are two types of cell division. In mitosis, the daughter cells each get two full sets of chromosomes, but in meiosis, they each only get one.

Mitosis vs meiosis

Both types of cell division begin in exactly the same way, but the end result is very different



CONTROLLING CELL DIVISION

CELL DIVISION MUST BE CONTROLLED, SO GROWTH STOPS WHEN WE ARE BIG ENOUGH, AND REPAIR COMES TO AN END WHEN A WOUND IS HEALED.

IN 2001, THREE SCIENTISTS WERE AWARDED THE NOBEL PRIZE IN PHYSIOLOGY OR MEDICINE FOR THEIR WORK TO UNCOVER THE MYSTERIES OF THE CELL CYCLE. PAUL NURSE, TIM HUNT, AND LELAND HARTWELL UNCOVERED SOME OF THE KEY MOLECULES RESPONSIBLE FOR DRIVING CELLS THROUGH THE DIFFERENT STAGES OF DIVISION. THEY REVEALED THE CHEMICAL 'START' BUTTON THAT KICKS THE CYCLE OFF, AND UNCOVERED SOME REGULATORS THAT ENSURE EACH STEP HAPPENS IN SEQUENCE. UNDERSTANDING THESE PROCESSES HAS HAD A HUGE IMPACT ON OTHER AREAS OF SCIENCE AND MEDICINE.

All about bow rosin

Many rosins come set in wooden blocks, while others are wrapped in cloth

How does tree sap help to make strings sing?

Learning to play an instrument takes time, patience and practise. String instruments are no exception, and to get to grips with them you need three bits of kit: the instrument, the bow and, to ensure that you can create those rich string tones, the rosin. This comes in the form of a sticky orange cake that needs to be rubbed along the strings of the bow before you play. Without rosin, the strings sound wispy and airy.

Rosin is made from pine tree sap that is heated and purified, with some additions that are specific to the manufacturer's recipe. It's then cooled and poured into moulds. Rosin types range in hardness, which in turn can produce a different sound from the strings.

The rosin works by making the hairs on the bow very sticky. As the bow slides across the strings, the extra friction from the rosin allows bow hairs to pick up the string, and as the bow keeps moving, the string is dropped and picked up repeatedly – resulting in the vibrations that create that signature string sound.

Rosin is a vital ingredient for playing a string instrument

How your brain understands science

Research reveals how your brain adapts to interpret complex ideas

Your brain makes links with rhythm to understand concepts like radio waves

While humanity has progressed leaps and bounds over the millennia, our brains have more or less stayed the same. But how do our prehistoric minds – that are wired for survival above all else – process the technologically advanced concepts of modern science?

To find out, a team of scientists from Carnegie Mellon University in the US analysed brain scans of physics and engineering students. Their neural activity was monitored using functional magnetic resonance imaging (fMRI), while they were asked to think about a series of 30 physics principles. A computer programme then created a map showing the active areas of the brain for each topic.

The results showed that the brain adapts itself to help us make sense of abstract ideas. We use parts of the brain associated with everyday activities to relate scientific principles to the real world. Concepts linked with causal motion (such as gravity) involved visualisation, while those linked to energy flow (such as heat transfer) used the same areas of the brain as sensing warmth. When pondering periodical concepts (such as sound waves), the areas associated with rhythm and music lit up. Principles associated with equations (such as velocity) activated the areas of the brain used for calculations.

By understanding how we learn and visualise various ideas, this research could help teachers find more effective ways of helping their students learn.

How you learn

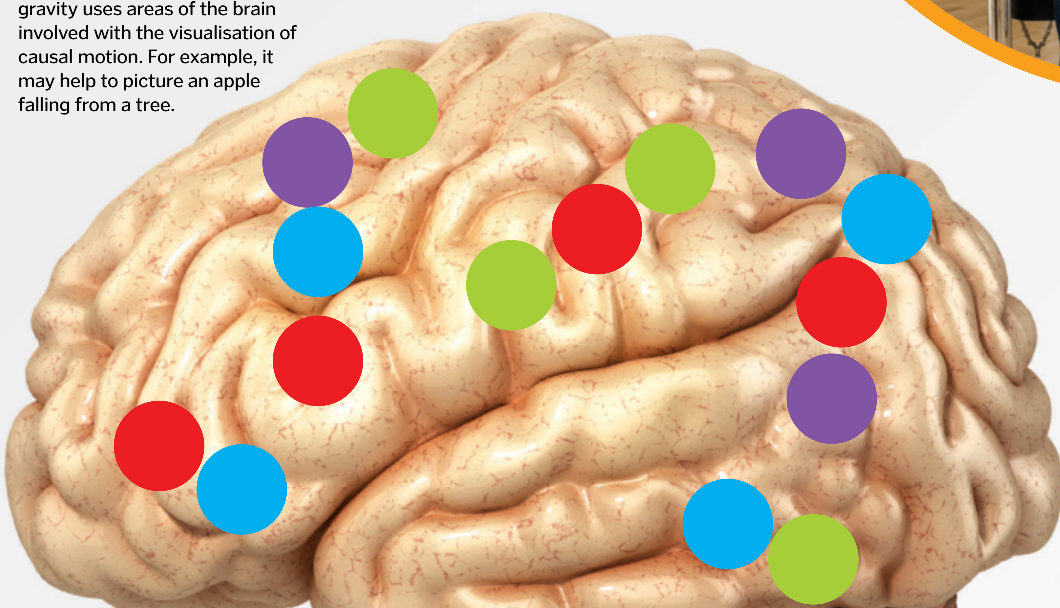
Which areas of your brain do you use to make sense of science?

Cause and effect

Understanding concepts like gravity uses areas of the brain involved with the visualisation of causal motion. For example, it may help to picture an apple falling from a tree.

Periodicity

When thinking about periodic concepts such as wavelength and frequency, the areas of the brain involved in processing rhythm – such as when you tap along to music – light up.



Equations

Principles represented with algebra or equations, like velocity and acceleration, tend to activate the same areas of the brain associated with understanding quantities and language.

Energy flow

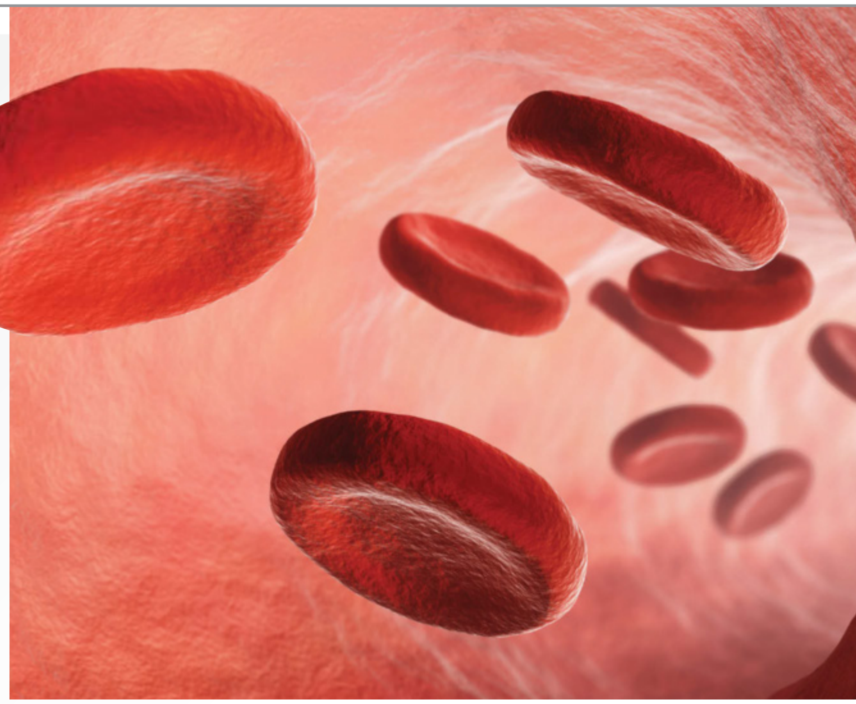
The parts activated when sensing radiated energy, such as sunlight, are also used to consider concepts of energy flow, such as current.

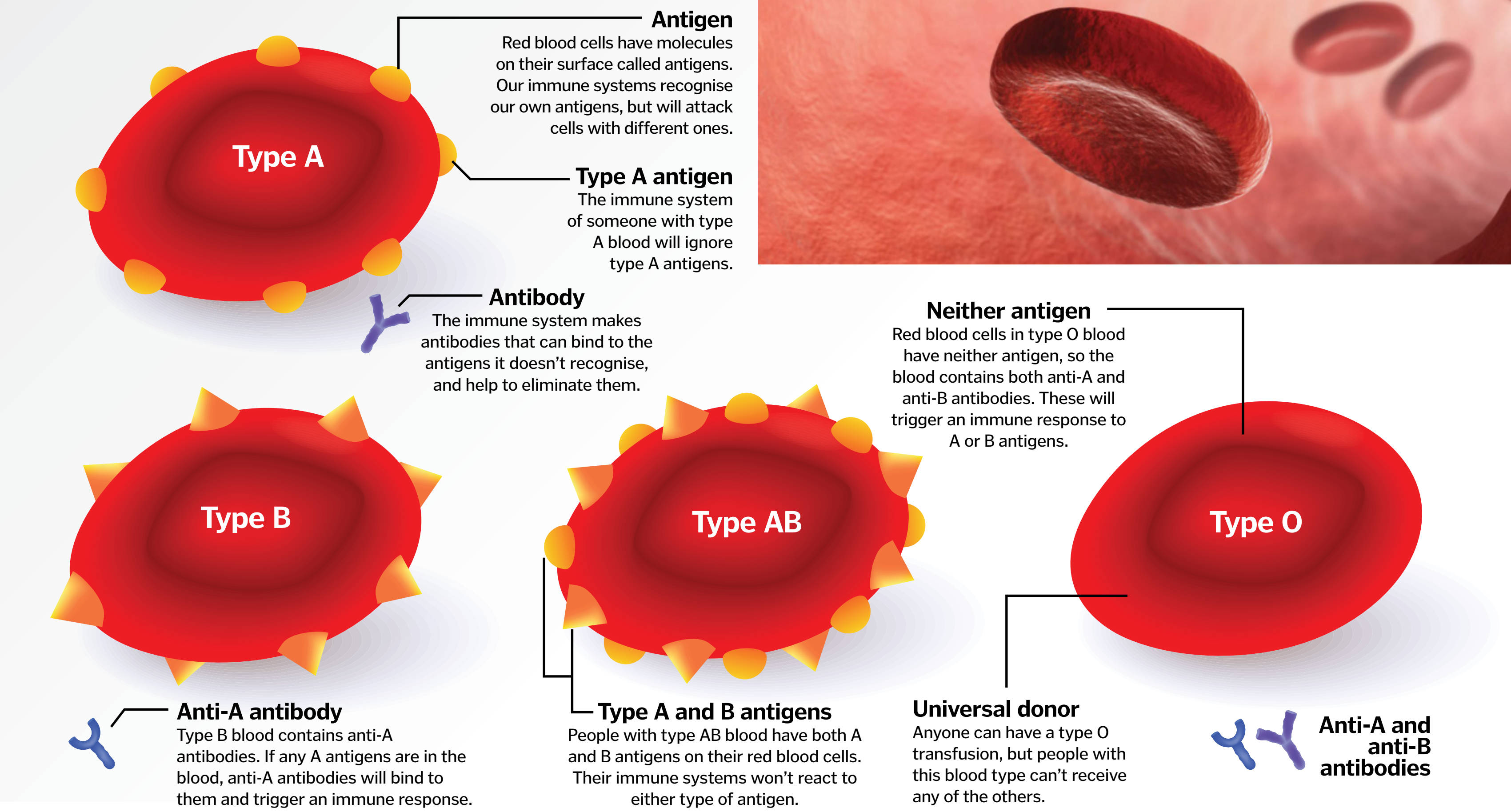
Inside your mind

Functional magnetic resonance imaging (fMRI) techniques enable neuroscientists to examine which areas of the brain are involved in specific processes. In a standard MRI scanner, a strong magnetic field forces the nuclei of water atoms in a person's body to align. When the magnetic field is switched off, the atoms return to their normal, random alignment, releasing energy in the process. As different parts of the body contain different amounts of water, the energy released indicates the type of tissue being scanned. Sensors located all around the scanner detect this energy and build a 3D picture of the body. Functional MRI employs the same principle, but is specifically used to detect changes in blood flow through the brain. Deoxygenated blood responds differently to oxygenated blood in a magnetic field, allowing researchers to see which areas of the brain use more oxygen (and so are more active) when carrying out particular tasks.

Blood types explained

If transfusions don't match, the immune system will attack the incoming cells





How clothes dry

Why doesn't cloth need to reach boiling point before the water evaporates?

We all know that water boils and evaporates at 100 degrees Celsius, but your favourite jumper would shrink to fit a doll if you had to heat it all the way to boiling point after every wash. Luckily, water can evaporate at room temperature too. This is because not every water molecule has the same amount of energy.

While your clothes as a whole might be the same temperature as the surrounding air, individual water molecules are whizzing around at different speeds. As they move, they bump into one another, and pass some of their energy on. Occasionally, a molecule gains enough energy to break away from the rest, moving away into the air as a gas. The warmer the clothes are, the more likely this is to happen.

The speed that clothes dry at is also affected by the amount of water that has already evaporated into the air – the humidity. Towels hung on a washing line on a windy day will dry much faster than those hung indoors in a damp bathroom, because the water vapour is quickly dissipated, keeping humidity low.

Wind helps to blow humid air away from clothes, speeding up drying time

China's rainbow mountains

The vivid colours of the Zhangye Danxia rock formations are a mineral marvel

China's Gansu Province, in the central north of the country, is home to a truly spectacular view. The striated colours of the Zhangye Danxia National Geological Park rise up from gullies and canyons in the rocks, and perfect stripes of earthy reds, oranges, whites and browns form craggy peaks that cover over 500 square kilometres.

The stripes in the rocks were originally horizontal, as layers of sandstone and other minerals built up over millions of years. Each layer was created as particles of rock were deposited through wind or water to form sediments. As new sediment layers gathered over time, their weight compacted the layers beneath until they cemented together to form rock.

We are able to see all of these cemented layers in the rock at Zhangye Danxia because tectonic activity has crumpled the Earth's crust and forced the rock upwards, exposing the different sediment sections in stunning rainbow stripes.

Some 50 million years ago, the Indian Plate smashed into the Eurasian Plate, causing the tectonic event that formed (and is still forming) the Himalaya mountain range. This caused a geological ripple effect, uplifting mountains and buckling the ground in different areas. In the case of the Zhangye Danxia Geological Park, the layers of sedimentary rock were exposed.

After the rainbow rocks were uplifted, other physical properties were then immediately at work, eroding and sculpting the landscape as it appears today. Sandstone is typically rather soft, and so forces of dust-laden wind, rushing water and the freezing and thawing of ice have all helped to mould the landforms.

The last piece of the rainbow mountain puzzle lies within the sediment layers themselves. Various minerals were deposited in the layers alongside the grains of sand and rock, and as these have been exposed to the elements as the ground uplifted, they have begun to oxidise and stain the sandstone layers. For example, one of the most prevalent colours in the landscape is a burnt copper hue. This occurs as elemental iron reacts with oxygen in the air – the same way that metal rusts – staining the landscape a dusky red.

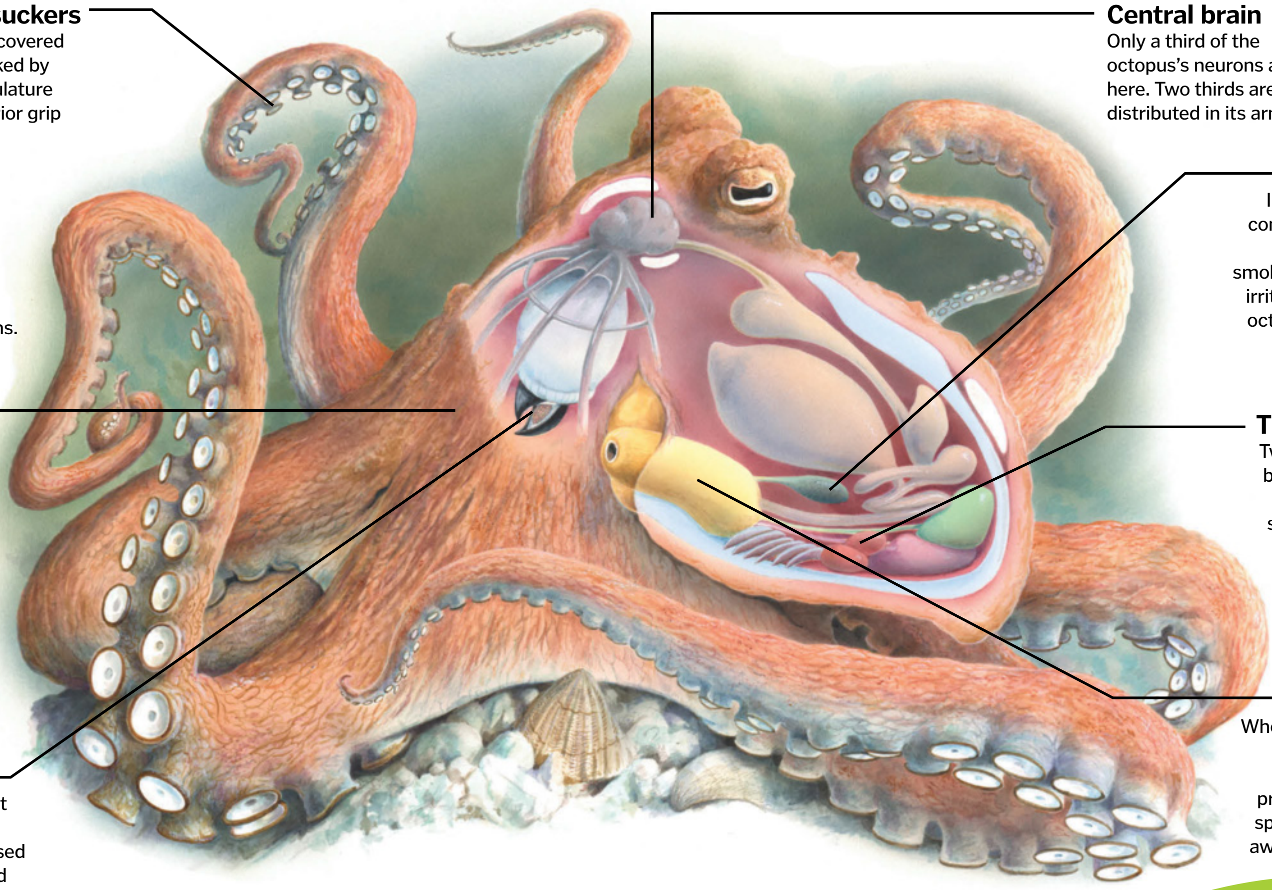
"Tectonic activity forced layers of rock upwards, exposing stunning rainbow stripes"

Inside an octopus

These curious-looking critters are the all-powerful heroes of the deep

Imagine a superhero with the ability to instantly disguise not only his skin to camouflage himself, but also his texture. Imagine that this guy possesses powerful rocket boosters to move him in super-quick time, and that he has a smokescreen ability to confuse his enemies. He can also fit through any gap, move in and out of water easily, walk on any substance the right way up and upside down, and even inject a deadly poison that turns his enemies to mush. Incredibly, the octopus boasts all of these amazing powers (apart from the rocket boosters – the octopus has a powerful siphon instead, using water pressure for quick getaways).

Octopuses are cephalopods. These animals are the aquatic, advanced and intelligent cousins of slugs and snails, in the phylum Mollusca. Octopuses live in sheltered, rocky coastlines across the world, and range in size from the tiny blue-ringed octopus that can fit on a thumbnail, to the colossal giant Pacific octopus with a nine-metre tentacle span. Their extraordinary abilities have inspired numerous tech inventions, from extra-strong suction cups to robotic limbs.



Arms and suckers
Eight arms are covered in suckers, backed by complex musculature providing superior grip and dexterity.

Mantle
The mantle, or 'head', contains all of the octopus's organs.

Beak
Resembling that of a parrot, this sharp beak is used for crushing and immobilising prey.

Central brain
Only a third of the octopus's neurons are here. Two thirds are distributed in its arms.

Ink gland
Ink is expelled to confuse predators, acting as both a smokescreen and an irritant to allow the octopus to escape.

Three hearts
Two hearts pump blood to the gills, while a third supplies the rest of the body.

Siphon
When tentacles will not move fast enough, the jet propulsion siphon speeds octopuses away from danger.

What are brinicles?

These so-called 'ice fingers of death' are a chilling phenomena

Found in both the Arctic and Antarctic seas, brinicles are formed when conditions are both calm and very cold. Usually occurring as winter sets in, these stalactite-like icy pillars grow downwards into the water from the sea ice.

As new sea ice forms, water freezes, and salt and other ions are forced out, producing salty brine. This fluid trickles through cracks and pores in the ice until it finds its way out.

The brine is much denser and colder than the seawater beneath the sea ice, which is usually around -1.9 degrees Celsius. As it hits the seawater, the brine begins to sink and the water around it freezes instantly. A brittle tube – or brinicle – is formed, and through this more brine trickles and freezes. Providing that sea conditions are calm, and no wildlife cruises past to knock it down, this process can continue until the brinicle reaches the seabed. Then it can spread out in a deadly frozen web, killing everything in its path. Scientists have reported seeing 'black pools of death' near brinicle formation, as the descending frozen brine has encased every nearby organism in ice.

Super-cold brine from the sea ice above kick-starts the formation of this deadly marine icicle

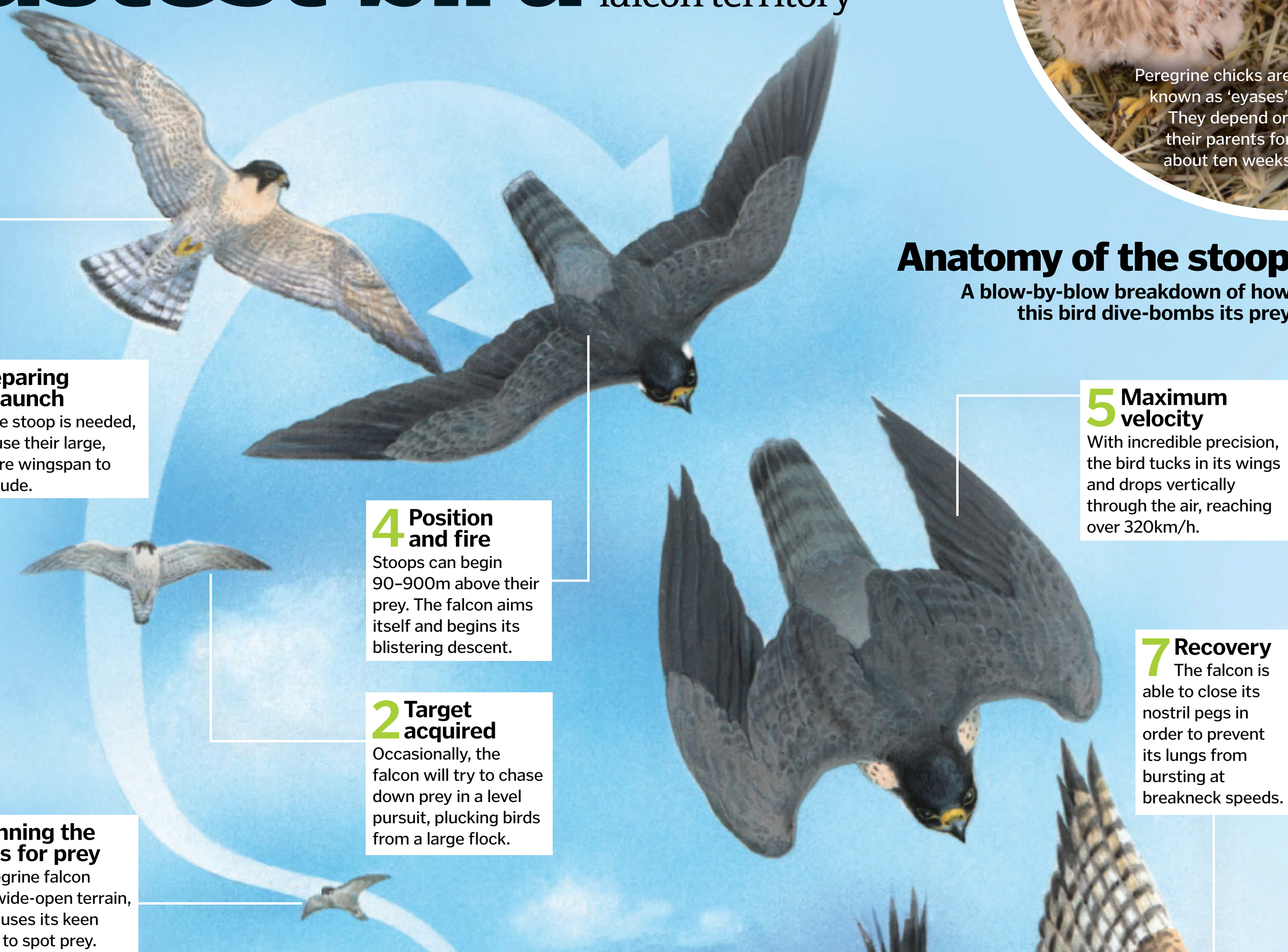
The world's fastest bird

Discover why you really don't want to be a pigeon in peregrine falcon territory

Peregrine chicks are known as 'eyases'. They depend on their parents for about ten weeks

Anatomy of the stoop

A blow-by-blow breakdown of how this bird dive-bombs its prey



1 Scanning the skies for prey
The peregrine falcon prefers wide-open terrain, where it uses its keen eyesight to spot prey.

2 Target acquired
Occasionally, the falcon will try to chase down prey in a level pursuit, plucking birds from a large flock.

3 Preparing to launch
When the stoop is needed, falcons use their large, one-metre wingspan to gain altitude.

4 Position and fire
Stoops can begin 90–900m above their prey. The falcon aims itself and begins its blistering descent.

5 Maximum velocity
With incredible precision, the bird tucks in its wings and drops vertically through the air, reaching over 320km/h.

6 Prey catch
The peregrine slams into its prey from above, with clenched feet. It will then either grab its prey from the air or let it fall and feed on the ground.

7 Recovery
The falcon is able to close its nostril pegs in order to prevent its lungs from bursting at breakneck speeds.

Found on all of the world's continents apart from Antarctica, the peregrine falcon is one of the most numerous birds of prey out there. And there's a reason for its phenomenal success: blistering speed. Pigeons in mid-flight can't escape the claws of this plummeting speed demon, which can exceed over 320 kilometres per hour. Known as the stoop, this manoeuvre sees the falcon climb in altitude before dive-bombing like a feathery torpedo.

Peregrine falcons are able to execute this move thanks to some precise physical adaptations. A streamlined body and tapered wings provide unrivalled velocity and thrust, and a razor-sharp beak and talons rarely let prey escape. A special third eyelid protects the bird's eyes at high speeds, and tubercles in their nostrils stick out like small, bony cones to deflect the rushing air, allowing the peregrine to catch its breath.

Each bird requires around 70 grams of food per day – about two blackbirds. However, when a monogamous breeding pair has chicks to feed, this dinner quota rises steeply. In just three weeks the chicks grow to ten times their birth weight. To support this swift growth, the peregrine needs to be a successful hunter to keep the family fed. Here's how they deliver the killer blow.

Wild encounters

Daring adventurer and wildlife enthusiast Steve Backshall discusses life on the edge

After a few years of living in the jungle, Steve Backshall earned the title 'Adventurer in Residence' for National Geographic Channel in 1998. He moved to the BBC in 2003, and has been making programmes about exploration and wildlife ever since. Backshall has taken on some of the world's most extreme mountain challenges, and come face-to-face with some of the planet's most fearsome predators. He confesses: "I am much more frightened in a big city on a Saturday night after pub closing time than I would be tracking lions on foot." Backshall is going on a UK tour to share stories and reveal some of the behind-the-scenes action from his expeditions. We spoke to him about survival tips, death-defying climbs and dancing with whales.

Your TV shows are edge-of-your-seat viewing, but what are some of the things we don't see on screen?
The outtakes usually involve animals doing the opposite of what I want. There are countless examples of animals ignoring me, breaking wind in my face, snapping and snarling, and doing other things that you don't expect them to.

What is the most difficult part of your job?
I think the most difficult part is how long it can take to find particular animals. Some things I can go out and find without too much trouble. Other things take inordinate amounts of effort and patience, and it can start to get quite stressful knowing somehow you've got to film this show and you haven't found the animal yet.

Have there been any moments in your career where you've genuinely feared for your life?
The expedition involving the first ascent of Amaurai Tepui, a vertical, sandstone-sided mountain in Venezuela. It was the follow-on to the highly successful first ascent we'd done a few years before. We were really excited about it, and it ended up being much more dangerous than we thought. We had rock-fall tumbling around our ears, a massive storm that raged in. It was unsafe. Even the guys on the team, who are some of the best climbers in the world, were terrified.

What is the greatest discovery you have made on an expedition?
I've been lucky enough to take the first light into cave systems that have never been explored, to make first ascents of mountains, first descents of white-water rivers, and to hold animals in my hand that are new to science. Perhaps the greatest of those was on the *Lost Land of the Volcano* expedition. We went to New Guinea with a team of scientists, and discovered as many as 20 new animals, including the world's largest species of giant rat, a new marsupial, a new bat and about ten new species of frog.

Do you have a bucket list of animals you want to see?
There are a lot of animals that I've put a huge amount of work into finding and still haven't seen. I've spent at least two months on the road looking for mountain lions and never seen one. I would love to go to the Karakoram in Pakistan to climb and look for snow leopards. That would be a dream. The longer I do this, the more I see what is left to do, and the bigger my list becomes.

What's the most beautiful thing you've experienced in nature?
Probably free-diving alongside a female sperm whale, who was interacting with me, almost dancing with me, underwater. She was

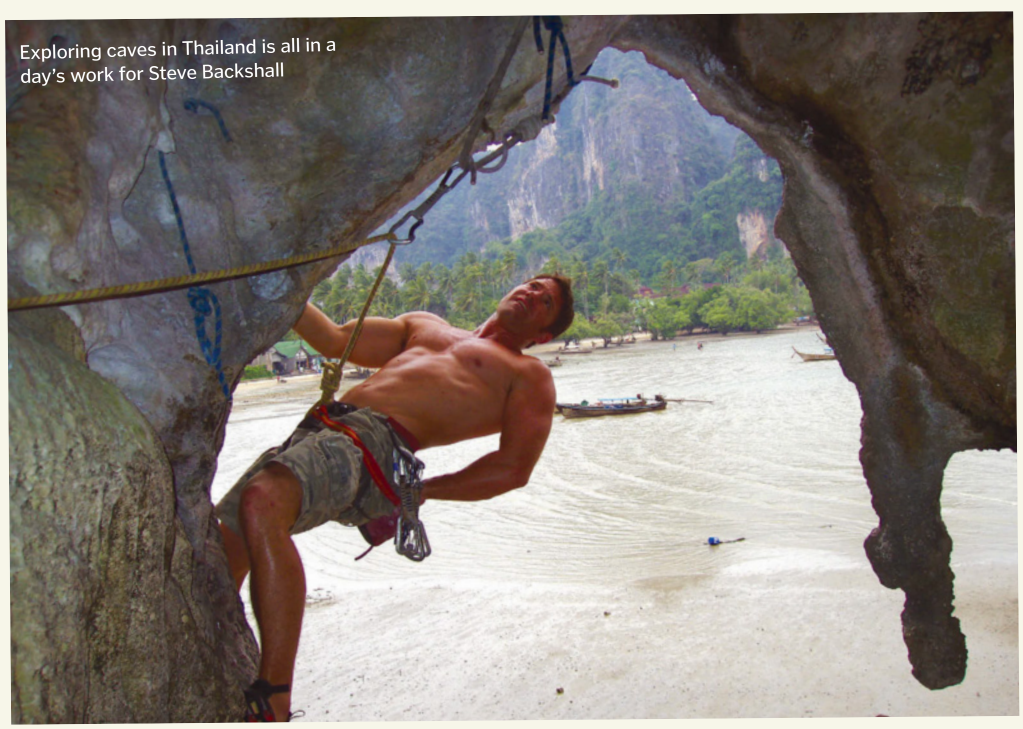
Close to extinction

As a dedicated ambassador for animal conservation, Steve Backshall reveals the three species disappearing from our planet faster than any others

Vultures
Numbers have plummeted since the 1980s due to the veterinary drug diclofenac. It's passed on to them when they eat the carcasses of animals that have been treated with the drug, and this causes kidney failure.

Frogs
The chytrid fungus is responsible for causing a global mass extinction of frogs. It infects a frog's skin, causing it to thicken and making it difficult for the animal to absorb the water and salts it needs to survive.

Sharks
The threat to sharks comes mainly from humans. Longlining, a technique for catching tuna, results in sharks getting hooked by accident. Fishermen will often then remove their fins to sell, due to the high demand for shark fin soup, a delicacy in Asia.



Exploring caves in Thailand is all in a day's work for Steve Backshall

Steve has wrestled with anacondas, vipers and cobras, but his only snakebite was from an adder in the UK

> "When you're working with predatory animals, never run"

mirroring my movements, replicating the same somersaults I was doing and looking me in the eye the whole time. It was like dancing a ballet with an animal that must have weighed ten tons.

What is the scariest animal on the planet?
The scariest is the hippo because it is so unpredictable. Snakes, scorpions and spiders almost have a set of rules for how they will behave in each situation. Hippos are much more intelligent than you might think, much faster and have a tendency to be aggressive as well, so that coupled with the fact that you don't know what they're going to do next makes them potentially the most dangerous animal to be around.

Where is your favourite place on Earth that you've visited so far?
Probably the Himalayas. I get a chance to go back there quite often. It's a place where the grandeur and majesty of the landscape is phenomenal. It changes constantly throughout the day, week and year. It's a place with many unclimbed peaks and great challenges, so I love it.

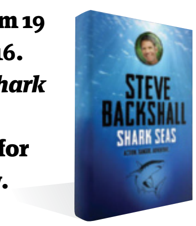
As an explorer, what item of kit would you never be without?
Superglue. It's a substance that apparently was developed in the Vietnam War for surgical use, and I still use it for that now. I apply it to blisters and minor cuts and it can also be used to hold together elements of your kit. It's one of the first things that I pack.

Steve has climbed some of the world's most dangerous mountains

What's the most useful survival tip you've ever been given?
When you're working with predatory animals, never run. Predators, generally speaking, have learnt over generations to fear us human beings. If you encounter even potentially very dangerous animals, such as big cats, in the wild, the chances of them attacking you are close to zero, unless you run. The second you run, you are doing what prey does and their instincts kick in and they will chase you down and attack you. Stand still and you'll probably get away with it.

What advice do you have for aspiring adventurers reading this?
Start small and close to home. Adventure begins in your own back yard. Learn about things you can find right here in the UK: the bugs and invertebrates that live in your garden. Particularly at this time of year, when it's warm, there will be plenty of things in your garden that you might not know about but have incredible, interesting lives.

Steve Backshall embarks on his nationwide Wild World theatre tour from 19 October to 20 November 2016. His new children's novel, *Shark Seas*, will be published in October. To book tickets for one of his shows, visit www.stevebackshall.com/tour.



WIN!

To get your hands on two tickets for Steve's Wild World tour, visit **howitworksdaily.com** and answer the following question by 11 August 2016.

What is the highest mountain in the world?

A. Mount Everest B. Mount Lhotse C. Mount Kilimanjaro

Terms and conditions
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Spotting ladybirds

Get to know a handful of the 46 different species in the UK

Ladybirds release foul-smelling blood from their knees if they feel threatened

Two-spotted ladybird

Along with the seven-spot, this species is one of the most common in the UK. Its appetite for pests has earned it a reputation as a gardener's best friend.

Ten-spot ladybird

This species doesn't always have ten spots, and comes in a range of colours, making it tricky to identify! Look out for the tell-tale orange legs.

14-spot ladybird

These spots are more rectangular and sometimes fused to form a chequered pattern. They can be found in grassland, woodland, towns and gardens.

16-spot ladybird

This ladybird is a herbivore and prefers to eat pollen, fungi and nectar rather than aphids. It's fairly small and hides away in areas of long, rough grassland.

22-spot ladybird

Unlike other ladybirds, this insect feeds on mildew, and can be found closer to the ground on low-growing shrubs. You can tell it apart from the 14-spot ladybird, as its spots never join up.

24-spot ladybird

What makes this specimen stand out is its wing casings covered in small, pale hairs, which gives it a matte appearance. This vegetarian species can be found in low-growing plants.

Bryony ladybird

First recorded in Britain in 1997, this critter was named after the plant it feeds on, white bryony. Its recent spread in Europe is believed to be due to global warming, as it enjoys hotter climes.

Larch ladybird

The more colourful the ladybird, the more toxic it is to predators, warning them away. As larch ladybirds don't have this defence mechanism, they blend in with the bark of their favourite conifer trees.

Eyed ladybird

Britain's largest ladybird is unmistakeable due to its black spots with yellow rings. They inhabit needled conifers and eat aphids. It's said that a single ladybird can eat up to 5,000 aphids in its lifetime.

Water ladybird

Most newly emerged ladybirds are bright yellow, and take a few hours to change colour. This species stays pale during the winter for camouflage, and turns red in the summer when active.

Kidney-spot ladybird

If you go down to the woods today, you could spy this curious-looking species. It's a carnivore that feasts on scale insects – tiny creepy crawlies that live on the bark of trees.

Orange ladybird

Once a rare variety, confined to ancient woodland, it has adapted to feed on the fungus that grows on sycamore and ash trees. In winter, it hibernates in leaf litter or on the sheltered parts of trees.

Pine ladybird

Easily recognisable for its comma-shaped spots and two smaller circular spots on its outer shell, this insect is named after one of its favourite trees to inhabit.

Harlequin ladybird

Originally from Asia, it has become one of the most invasive species in the UK, preying on native ladybirds and causing the numbers of two-spots to plummet.

Striped ladybird

Sporting stripes rather than spots, this chestnut-coloured beetle has a strong preference for Scots pine trees and is widely distributed throughout the UK.

Cream-streaked ladybird

This species rests on conifers, where its markings blend in with the surroundings. First recorded in Suffolk in the 1930s, it has spread through most of the country.

SAVE RHINOS NOW

10% OF OUR PROFITS HELP FIGHT POACHING

An animal in crisis
In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

Make a difference today
Ol Pejeta is a leading conservancy fighting against this cruelty. It needs more funds so more rangers and surveillance can be deployed on the ground to save rhinos from this horrible treatment.

Join World of Animals
World of Animals magazine takes a stand against these atrocities and is proud to be in partnership with the Ol Pejeta Conservancy – 10% of our profits go towards saving rhinos in the fight against poaching

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THE ICE AGE

Uncover the lost world & giant beasts of frozen Earth

For most of Earth's history, the planet has been free of ice, even at the poles. However, for the last 2.4 billion years, Earth has been cycling in and out of freezing ice ages. For millions of years at a time, temperatures plummet and large areas of the globe become trapped under sheets of ice. These glacial periods start gradually. Snow falls during the winter, and fails to melt in the summer, and over time, layer upon layer is built up. The white surface reflects sunlight back into space, and a cycle of cooling begins.

Vast glaciers form at the poles, creeping inwards towards the equator, and Earth's water is locked away into slowly moving ice. As it creeps along, it carves great scars into the landscape beneath. When Earth's water freezes, sea levels drop, revealing land once hidden beneath the oceans. Winds and currents change direction, and even those places untouched by ice undergo significant climate change.

There have been at least five ice ages so far, the first of which transformed the entire planet into a giant snowball. However, within these periods of extreme chill, there have been occasional bursts of warmth. During each ice age, the Earth cycles in and out of glaciation, freezing for tens of thousands of years, thawing temporarily, and then freezing again. As the glaciers warm, water floods back across the land, filling valleys and carving out new tracks in the landscape. Sea levels rise, and winds and currents shift. In fact, we are in the middle of an ice age right now – but we are in a temporary thaw that began around 11,000 years ago. These warm periods are known as 'interglacials' and we don't know exactly how long they last for. Ice sheets still cover Antarctica and Greenland, trapping 75 per cent of Earth's fresh water, and when these finally melt, it will mark the end of the current ice age. Until then, join us as we delve into the history of ice on Earth.

"Vast glaciers form at the poles, creeping towards the equator"

TRIGGER POINT

Earth's temperature depends on where it's at in its Milankovitch cycles

The Sun warms our planet, but the amount of heat we receive varies over years, decades and millennia. This is because Earth's orbit, tilt and axis angle fluctuate in three different patterns, known as the Milankovitch cycles.

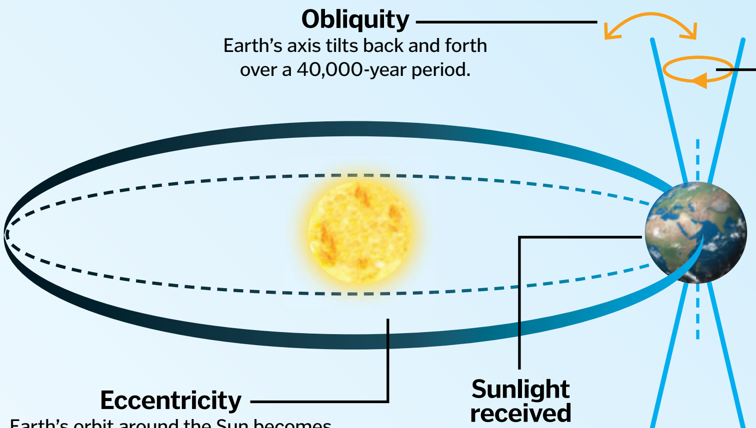
The first cycle is known as eccentricity. Earth moves around the Sun in an elliptical orbit, coming in close and then moving further away. However, the shape of this orbit changes over time, becoming more elongated (or 'eccentric') and rounder in a cycle that lasts 100,000 years.

The second cycle, known as obliquity, refers to the tilt of Earth relative to the plane of its orbit, which varies from 22.1 to 24.5 degrees over a 40,000-year period. The bigger the tilt, the more extreme the seasons are on our planet. Finally, Earth also wobbles as it spins, a little like a spinning top as it slows down. This wobble is known as precession, and it takes 26,000-years to complete one cycle.

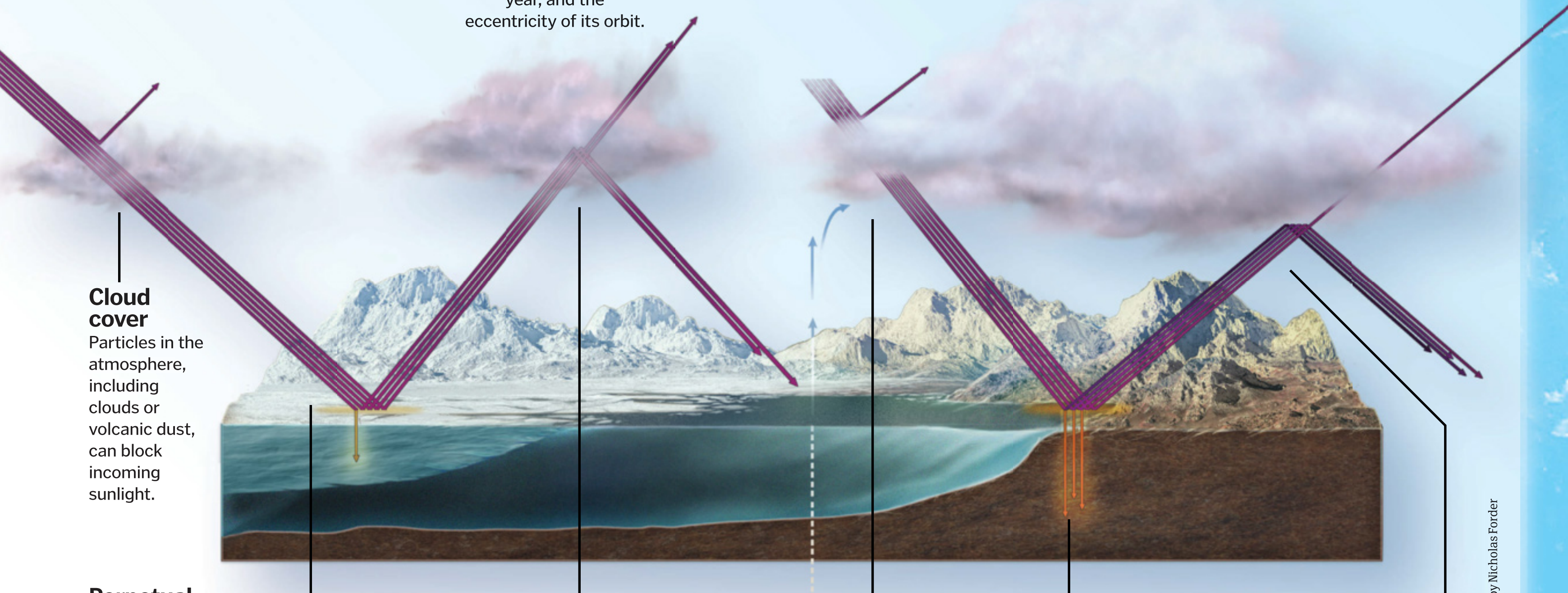
The amount of solar energy that reaches Earth depends on where it is in all three Milankovitch cycles. At times when the planet receives the least energy, summer temperatures are coldest, and an ice age may be triggered. But the planet's fate also depends on the position of continents, ocean circulation and composition of the atmosphere.

The making of an ice age

Several factors come together to tip the Earth into a big freeze

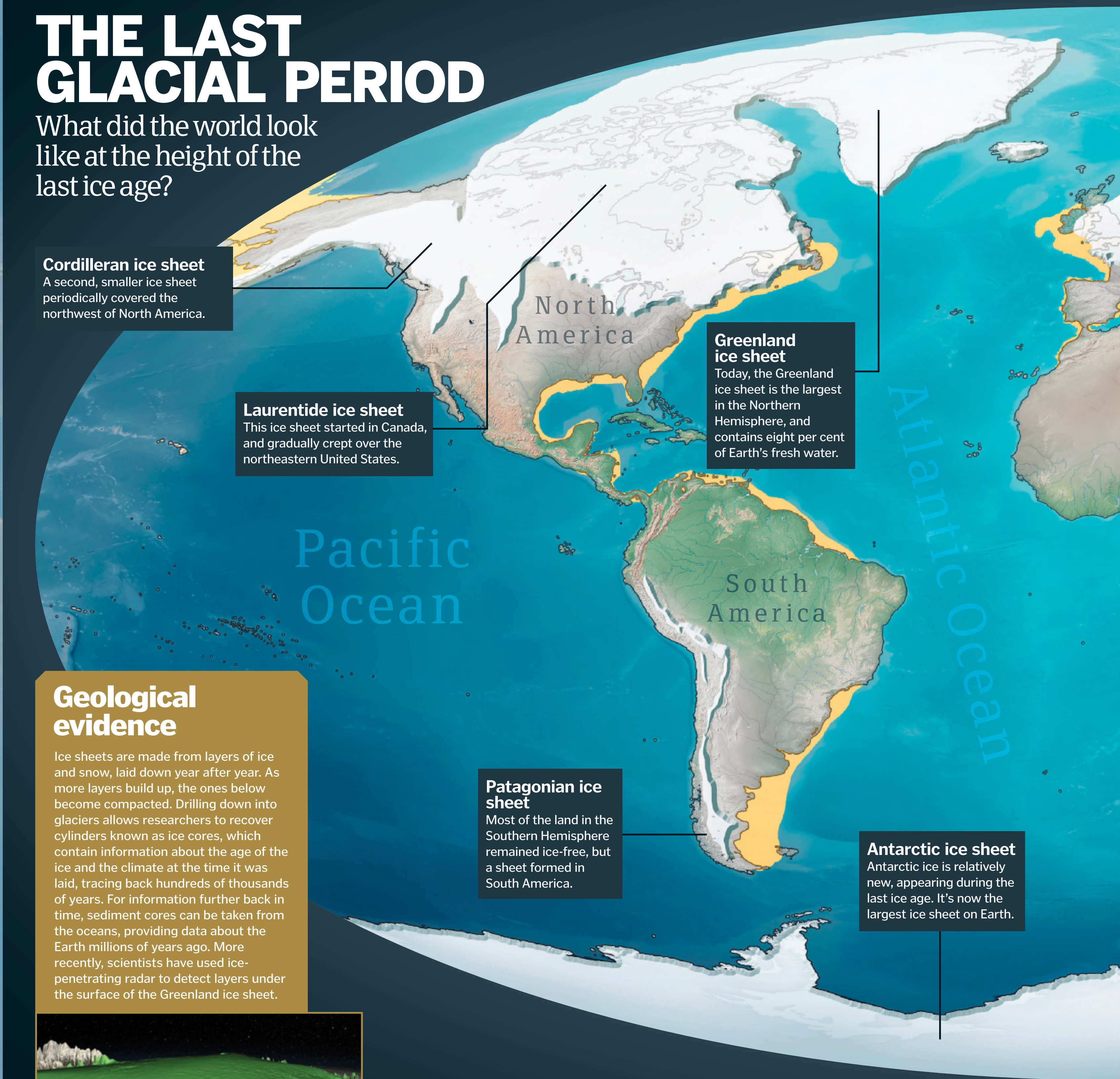


When Earth's water freezes, sea levels drop, and the land beneath is revealed



THE LAST GLACIAL PERIOD

What did the world look like at the height of the last ice age?



Cordilleran ice sheet
A second, smaller ice sheet periodically covered the northwest of North America.

Laurentide ice sheet
This ice sheet started in Canada, and gradually crept over the northeastern United States.

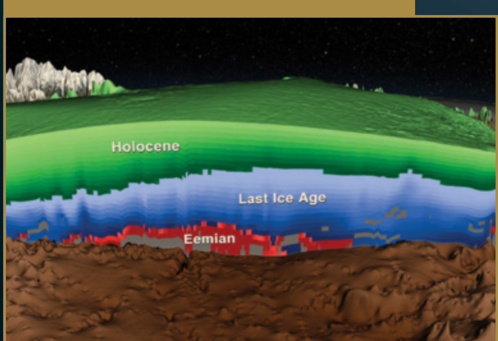
Greenland ice sheet
Today, the Greenland ice sheet is the largest in the Northern Hemisphere, and contains eight per cent of Earth's fresh water.

Patagonian ice sheet
Most of the land in the Southern Hemisphere remained ice-free, but a sheet formed in South America.

Antarctic ice sheet
Antarctic ice is relatively new, appearing during the last ice age. It's now the largest ice sheet on Earth.

Geological evidence

Ice sheets are made from layers of ice and snow, laid down year after year. As more layers build up, the ones below become compacted. Drilling down into glaciers allows researchers to recover cylinders known as ice cores, which contain information about the age of the ice and the climate at the time it was laid, tracing back hundreds of thousands of years. For information further back in time, sediment cores can be taken from the oceans, providing data about the Earth millions of years ago. More recently, scientists have used ice-penetrating radar to detect layers under the surface of the Greenland ice sheet.



The Greenland ice sheet contains evidence of the last ice age, and the warm period that preceded it

Earth's ice through the ages

Our landscape has changed dramatically over the last 2.4 billion years

3 BILLION YRS AGO

1

2 BILLION YRS AGO

2.4-2.1 BILLION YRS AGO

1 Snowball Earth
Our entire planet froze over during the first ever ice age, called the Huronian.

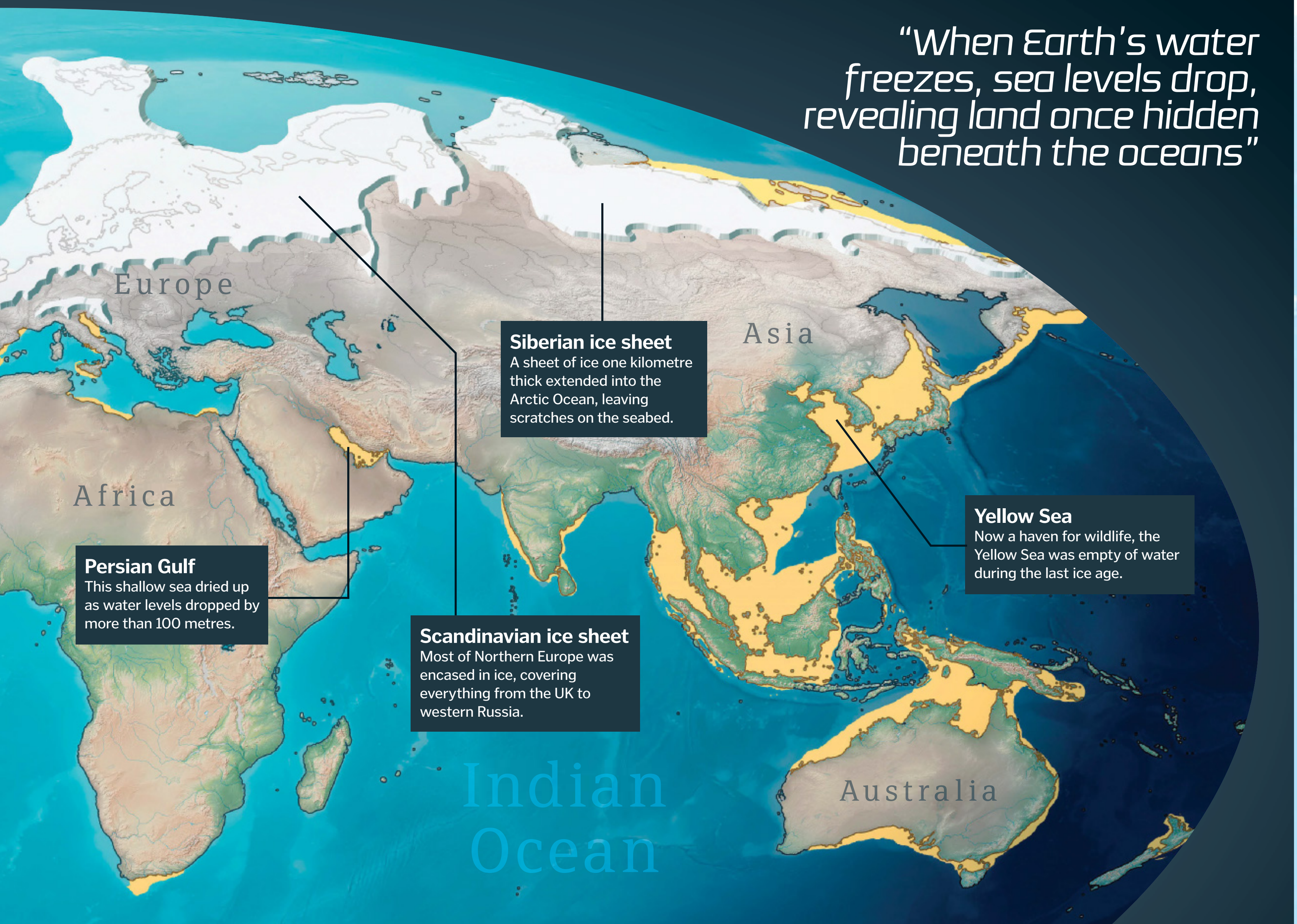
850-630 MILLION YRS AGO

2 Slushball Earth
During the Cryogenian ice age, a band of liquid ocean remained at the equator.

460-430 MILLION YRS AGO

3 Mass extinction
The Andean-Saharan ice age accompanied the second largest mass extinction in history.

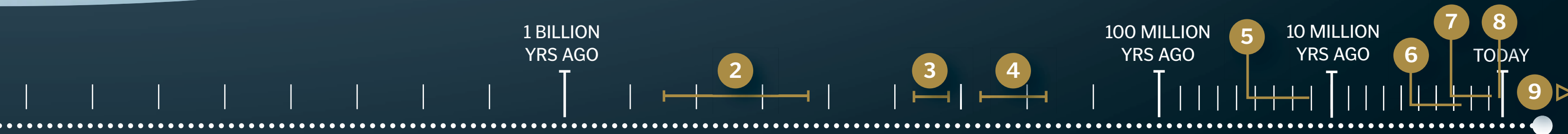
"When Earth's water freezes, sea levels drop, revealing land once hidden beneath the oceans"



Land bridges

When Earth's water freezes into glaciers, sea levels drop, exposing land once hidden beneath the waves. These 'land bridges' connect islands and continents, allowing animals to move from one place to another. The most well-known is the Bering Land Bridge, which once linked Siberia to Alaska, closing the gap between Asia and North America. This bridge provided a sheltered path that took early humans to the Americas. In the past, solid ground has also appeared between the UK and Europe, connecting the islands of the Indonesian archipelago, and linking Australia to New Guinea.

Today, the Bering Strait is flooded with water



360-260 MILLION YRS AGO

4 The arrival of plants

Plants sucked carbon dioxide from the air, causing the Karoo ice age.

20 MILLION YRS AGO

5 The making of Antarctica

The beginnings of the Antarctic ice sheet started to form.

2.5 MILLION YRS AGO

6 Quaternary ice age

The latest cold snap started very recently, and is still going on to this day.

11,000 YRS AGO

7 Interglacial period

We are in the middle of a short intermission in the current ice age.

1300-1800 YRS AGO

8 Little Ice Age

In recent history, Earth experienced a sharp drop in temperature.

THE FUTURE...

9 Next ice age

Human activity is warming the planet, and the date of the next ice age is uncertain.

THE SURVIVORS

Meet the giant beasts that conquered the frozen wilderness

Before the end of the last ice age, Earth was inhabited by weird and wonderful mammalian megafauna. Food was abundant, allowing animals to grow to enormous sizes, and the larger they got, the more protection they had from the cold. Not all of the animals that lived during the ice age inhabited the coldest parts of the planet; many, like ground sloths and sabre-toothed cats, preferred to live in warmer and more temperate regions further south.

There were also many true ice survivors, including fur-covered woolly mammoths, musk oxen, and giant dire wolves. Their stocky bodies helped to minimise heat loss through their skin, and layers of fat and hair provided thick insulation. However, when the temperatures started to rise, these animals began to struggle.

During interglacial periods, glaciers melt and sea levels rise; valleys flood and lakes appear in the landscape. Ocean currents change direction, and winds shift. And as if that weren't enough pressure, at the end of this particular ice age, humans were roaming the landscape with spears. Our ancestors competed with top predators, and hunted some of the largest animals. Mammoths and mastodons were 'keystone' species, so large and numerous that their activities carved out vital niches that other animals needed for survival. But around 50,000 years ago, the ice age megafauna started to die out, and by the time the glaciers had retreated, at least 177 large mammal species were extinct.

Sabre-toothed cats had 15cm canines

"At the end of the ice age, humans were roaming the landscape with spears"

Sabre-toothed cat

There were three species of sabre-toothed cat, all found in the Americas. They were similar in size to modern lions, but with shorter legs and significantly larger teeth. Their curved canines were over 15 centimetres long, and their mouths opened almost twice as wide as those of modern cats. Surprisingly, however, their bite force was nowhere near as powerful as a lion's. Although they are often called tigers, the colour and patterning of their fur is not known and they are not closely related to modern tigers.

Woolly mammoth

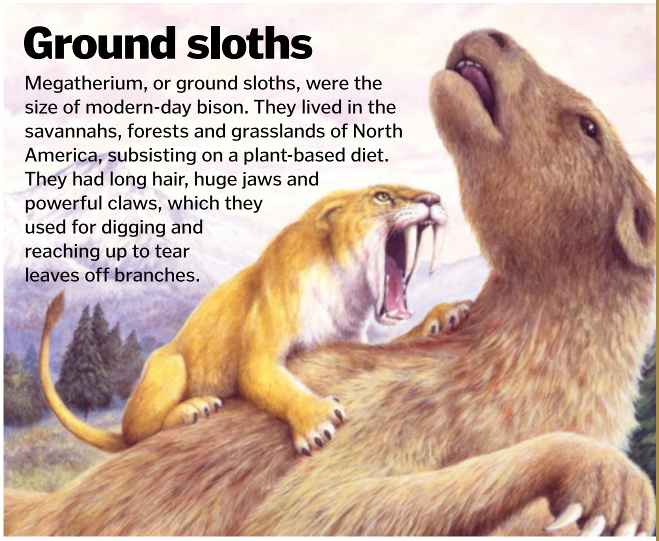
These iconic ice age animals were covered in thick hair and layers of insulating fat. Unlike modern elephants that have large ears to aid heat loss, mammoths had small ears to conserve heat, and even their blood was adapted to cold weather. Their haemoglobin – the molecule that transports oxygen in the blood – functioned over a much wider temperature range than that of modern elephants, allowing oxygen to reach their extremities even in the freezing cold.

Dire wolf

These prehistoric wolves were slightly larger than their modern counterparts, with short legs, broad heads, and smaller brains. While grey wolves use speed and teamwork to wear their prey down, these snow hunters are thought to have preferred ambush tactics. Grey wolves existed alongside these fearsome hunters but 10,000 years ago, dire wolves had disappeared, along with other ice age predators like sabre-toothed cats and American lions.

Ground sloths

Megatherium, or ground sloths, were the size of modern-day bison. They lived in the savannahs, forests and grasslands of North America, subsisting on a plant-based diet. They had long hair, huge jaws and powerful claws, which they used for digging and reaching up to tear leaves off branches.



Short-faced bear

These ferocious bears are thought to have been the fastest of their kind, with front-facing feet that allowed them to reach speeds of more than 64 kilometres per hour. Their blunt snouts are thought to have helped them to get the maximum amount of air into their lungs while chasing their prey.

Glyptodonts

These bizarre-looking beasts were the size of a car, and the heaviest weighed more than a ton. Related to modern armadillos, they had a protective exoskeleton made from plates of bone called osteoderms, and a fearsome-looking clubbed tail. While armadillos can flex their armour, glyptodonts had fused bones with rigid shells that turned them into walking tanks.

Other ice age critters

Giant beaver

These rodents were the size of bears, but their teeth were markedly different to those of modern beavers. There is no evidence that they built dams.

Ice age horse

Horses went extinct in the Americas 11,000 years ago, but they managed to survive in Eurasia and Africa. Modern horses in the Americas – as well as donkeys and asses – are the descendents of these survivors.

Musk ox

These heavy-set, woolly animals almost went extinct due to hunting during the last ice age, and the warming climate that followed. There are still some musk oxen in Canada today, but their numbers are vastly reduced.

American lion

Larger than modern lions, and with longer legs, these animals would have had to compete with sabre-toothed cats and short-faced bears for prey.

Mastodon

Relatives of mammoths, these elephant-like animals had long trunks and woolly hair. Some fossilised bones show evidence of tuberculosis, which could have been one of the factors leading to their extinction.

Stag-moose

With stilt-like legs, these animals were adapted to pick their way through damp marshland and boggy ground. They had large, complex antlers and faces similar to modern-day elk.

LIVING IN A FROZEN WORLD

How did early humans survive the ice age?

Early humans had begun to explore Europe, Asia and North America by the time the last glacial period set in around 110,000 years ago – this is what is often referred to as *the* Ice Age. Although many humans lived far enough to the south that they escaped the advancing ice, some had to brave fierce drops in temperature. They had three choices: migrate, adapt or die.

Humans weren't alone in their struggle. Another hominid species, Neanderthals, were also attempting to brave the cold. They were stockier than humans, with shorter forearms and shins, which would have helped to conserve body heat. Neanderthals built simple shelters, used animal skins for blankets, and kept themselves warm beside wood-fuelled fires. In mild conditions, they hunted red deer, and as it grew colder, they switched to reindeer. Eventually, when the landscape froze, they moved south in search of warmth.

However, humans had something that Neanderthals did not: advanced technology and sophisticated communication skills. They moved south to escape the worst of the cold, but some were still exposed to chilling temperatures and challenging environments. They learnt to burn bones when wood was scarce, built more complex shelters, and traded over great distances, thereby making the most of their social networks.

Humans banded together and used sharp tools to hunt large animals like mammoths and mastodons, securing the biggest calorie payoff for their efforts. And when the meat had been consumed, they made needles and stitched the skins into well-fitting clothes. Neanderthals were extinct by the time of the glacial maximum, 20,000 years ago, but humans' intelligence and ingenuity helped them to cling on through the cold.

"Humans moved south to escape the worst of the cold"

The secrets of survival

Clever thinking and advanced technology allowed humans to make it out alive

THE END OF THE ICE AGE

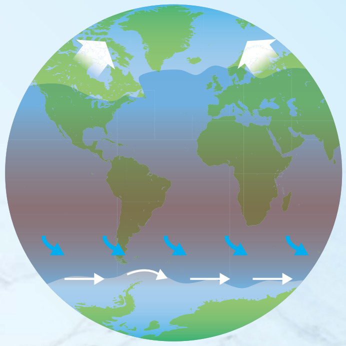
What caused frozen Earth to thaw?

20,000 years ago

Towards the end of the last ice age, Earth tilted on its orbit, pointing the Northern Hemisphere towards the Sun. With more light and more heat striking the frozen surface, ice sheets in this area finally began to melt, and water flooded into the Atlantic Ocean.

19,000 years ago

The influx of cold water into the Atlantic disrupted the ocean currents, slowing the flow of warm water moving up from the south. With nowhere to go, these hot streams remained in the Southern Hemisphere, warming oceans and melting ice.



17,500 years ago

The flow of ocean currents affects the wind, and with the disruption in the north, winds pushed downwards. As the southern glaciers melted, more water was released into the oceans, and with it came carbon dioxide – a greenhouse gas that helps to trap heat.

Using the landscape
Sheltered areas in low-lying land would have provided some protection against the cold weather.

Migration
Moving south, and sticking to sheltered, ice-free areas would have helped humans to survive the worst of the cold.

Trade
Different groups traded across long distances, helping to maximise the use of different environments.

Shelter
Some shelters were built with hearths inside to provide additional heat.

Community
Symbols and communication allowed groups of people to work together to plan for the future.

Fire
Wood was scarce in some places, so humans burnt bones as fuel.

Is winter coming?

The impact of humans on Earth could affect the forecast

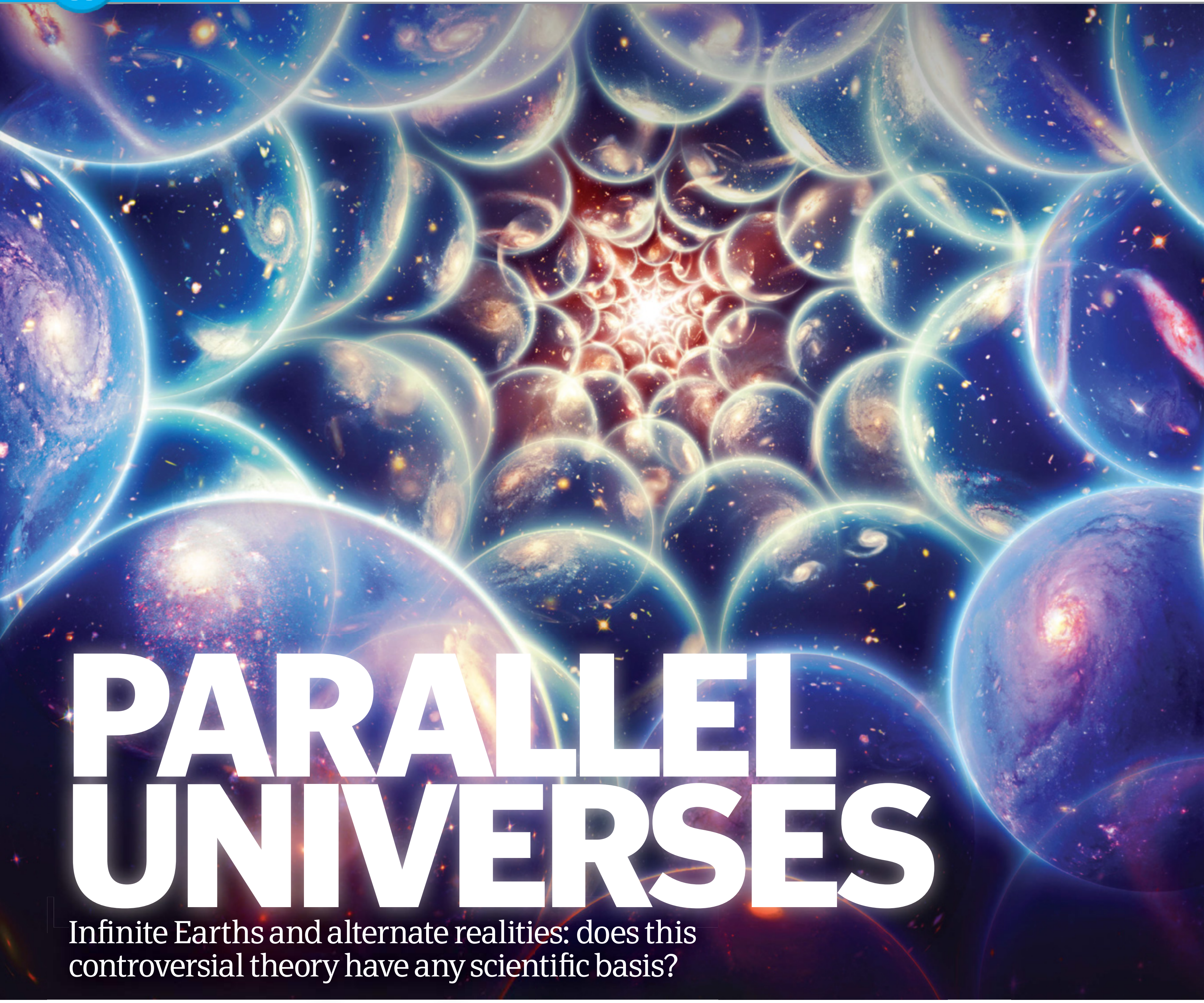
Technically, we are still in the middle of an ice age. The cold period that saw the rise and fall of woolly mammoths has not yet ended. We are in an interglacial period, and if history is anything to go by, these last for around 15,000 to 20,000 years.

11,000 years have already passed, but whether another cold snap is around the corner is a matter of debate. In the late 17th century, there was a Little Ice Age, during which time rivers froze and ice fields refused to melt during the summer. This is thought to have been caused by a period known as the Maunder Minimum.

The Sun's changing magnetic field produces sunspots, which normally increase and decrease in a pattern that repeats every 11 years, but during the Little Ice Age, this cycle all but stopped. For 70 years, there were only around 50 recorded spots, when normally there would have been closer to 50,000.

In 2008, sunspots disappeared again, and when they eventually returned in 2014, they were weaker than at any other time on record. However, since the 17th century, humans have been busy expanding and industrialising, and, at least in part thanks to us, global temperatures are rising. Whether this will have an effect on the ice age cycle remains to be seen.

The Little Ice Age is thought to have inspired tales of white Christmases



PARALLEL UNIVERSES

Infinite Earths and alternate realities: does this controversial theory have any scientific basis?

It's an understatement to say that the multiverse theory is one of the most controversial theories in science. In fact, merely putting this in the Space section of the magazine, and not a newly created Theology section, would ruffle a few astrophysicists' feathers. But why is this the case, and is there any basis for suggesting we live in a multiverse?

The origins of the multiverse theory are a grey area. Some, like David Deutsch in his book *The Beginning of Infinity*, point to Erwin Schrödinger and his famous equation. This broadly introduced the idea of quantum mechanics, in which a particle can be in two states at once, in the first half of the 20th century. It would be many years until the broader implications of the theory were given serious thought, though.

You're probably more familiar with the multiverse theory in different terms – parallel universes – so let's begin there. At its core, the multiverse theory suggests that our universe is not alone, but perhaps one of many in some form or another. Just as we discovered Earth was one of many planets, and that the Milky Way was one of many galaxies, some scientists think the same could be said of the universe.

As of yet, we have no direct evidence for multiverses (and even that prospect is contentious, which we'll come on to later). But our best indirect evidence for its existence is a peculiar one. It stems from how exact certain mathematical constants in the universe are. The cosmological constant, for example, is a value for the energy density of the vacuum of space. Its existence explains how the universe is expanding at an ever-increasing speed, something first discovered in 1998.

But the cosmological constant is 120 orders of magnitude smaller (that is, ten to the power of minus 120) than theory predicts it should be. Thus, even a small change in its value would have rendered our universe a mess of nothingness after the Big Bang. So, too, for the values of dark energy. How were these mathematical constants so finely created?

"If [dark energy] had been any bigger, there would have been enough repulsion from it to overwhelm the gravity that drew the galaxies together, drew the stars together, and drew Earth together," Stanford physicist Leonard Susskind told *Discover Magazine* in 2008. "It's one of the

greatest mysteries in physics. All we know is that if it were much bigger we wouldn't be here to ask about it."

The multiverse theory has an answer, though. It suggests that in our universe, the cosmological constant is exactly the right value for everything as we know it to exist. But there are an infinite number of other universes, where it is ever so slightly different.

Working on the pretence that this is true, what form would these other universes take? That's the tricky part. There are a large number of theories, from Max Tegmark's four levels of classification (explained later), to M-theory (which encompasses string theory), to cyclic theories, where the universe is in an infinite number of cycles between Big Bangs and Big Crunches.

Tegmark's four levels encompass the broader multiverse theories. The Massachusetts Institute of Technology professor suggested them in 2003, presenting them as a way to classify ideas for the multiverse. "Parallel universes are not a theory, but a prediction of certain theories," he said in his 2014 book *Our Mathematical Universe*. The first level deals with the observable universe, which is the extent to which we can see in the universe. Owing to the finite speed of light, we are only able to see as far as light has been able to travel to us since the Big Bang, 13.8 billion years ago. Due to the expansion of the universe, though, we are able to see light that is now more than 42 billion light years from us, which we call the observable universe. But we cannot see beyond this; what is there, we just don't know.

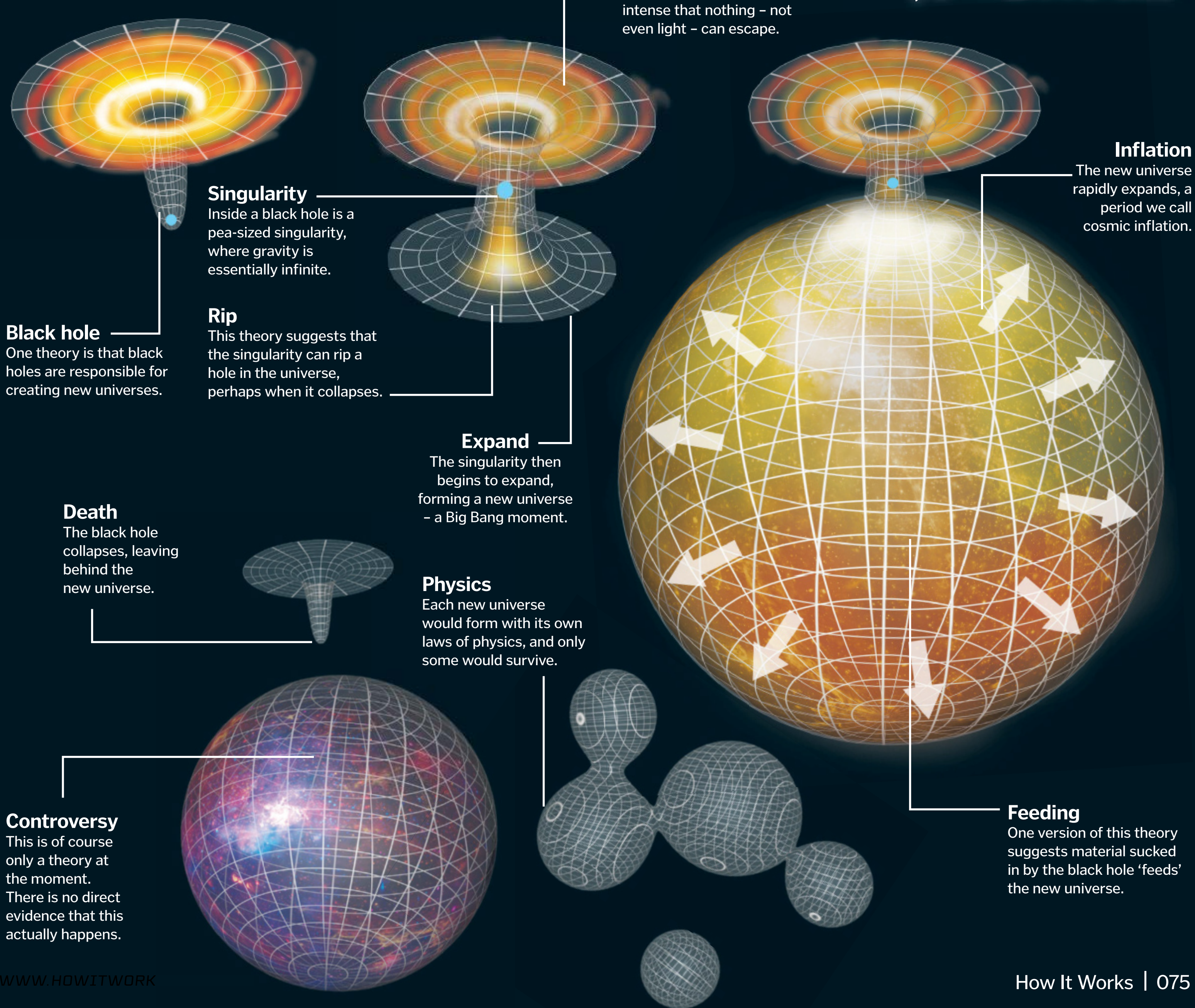
Tegmark's first multiverse level suggests that there is no end. Instead, the universe just keeps going and going, infinitely. If true, this would create an infinite number of instances for everything to occur. So, at some astronomical distance away from us, we would find an Earth exactly the same as ours, and you would find yourself sitting there reading this very article.

The second level is similar to the first, but proposes that while the whole multiverse is expanding, there are regions within it that expand at different rates, forming bubbles of self-confined space – in other words, bubble universes. Our universe would be one bubble, with an untold number of other bubbles beyond, each with their own laws of physics. In 2015, a later, widely discredited theory suggested our

Building a multiverse

Are universes born in black holes?

"As of yet, we have no direct evidence for multiverses"



bubble universe had actually 'bumped' into one another, producing a noticeable glow in the far reaches of space.

In the third level, things start to get a little bit strange. Like the first, it suggests that the laws of physics are the same everywhere, but rather than different universes being separated by distance, as in the second level, they are in fact separated by time. The laws of quantum mechanics, as mentioned earlier, allow for a large number of uncertainties and possible futures (for example, whether Schrödinger's famous 'cat in the box' is dead or alive). In this level, all of these possibilities would play out. Every single eventuality would occur, and each time, a new universe would be created along with it. For us as observers, though, we only see one universe – our own.

The fourth and final level, the mathematical multiverse, is fairly difficult to comprehend. It is Tegmark's own theory, presented in *Our Mathematical Universe*. It essentially implies that the universe is composed entirely of mathematics, and we are merely constructs within that. But the book and theory have come under some heavy criticism.

One of the main arguments against the multiverse theory, though, is that it fails one of the very cornerstones of science itself: falsifiability. This is the ultimate test for any scientific theory, namely that it can be proven wrong. For example, if you put forward the theory that every animal on Earth had four legs, someone else could refute that theory by finding an animal with more or less than four.

No multiverse theory is currently falsifiable. We simply don't have the means to disprove some of the claims being made. We will never be able to journey beyond the observable universe, and

Different types of multiverse

"We have no way of jumping to another universe"

LEVEL ONE: An extension

Our views into the universe are limited by the age of the universe. We cannot see further than the time light has had to travel to us, which when you take the expansion of the universe into account, comes to 42 billion light years.

But this multiverse theory suggests that, beyond this distance, the universe continues into infinity. And this would mean that eventually, by chance, everything would start to repeat itself – even Earth itself. It will be impossible to ever know what is beyond our observable universe though, without finding some fanciful way to travel faster than light. Until then, we may never know what is beyond our vision.

Learn more

To learn more about multiverse theories, check out Issue 46 of our sister magazine, **All About Space**, which goes into far more detail on the controversial topic.

LEVEL TWO: The bubble universe

This theory proposes that there are many 'bubble' universes living alongside each other. The key behind the theory is cosmic inflation, which is the period of rapid expansion the universe went through in its first trillionth of a trillionth of a trillionth of a second. This ultimately gave rise to the universe as we know it.

According to this theory, different regions of space expanded at different rates, forming their own 'bubble' regions alongside ours. In theory, there could be an infinite number of these bubble universes alongside ours, with a contentious version suggesting each has its own laws of physics.

thus could never disprove the notion that there are other parallel bubble universes out there, or an infinite universe. As such, many argue that the multiverse theory should not be treated as a theory at all. It should be condemned to the pseudoscience bin.

"The trouble is that no possible astronomical observations can ever see those other universes," said cosmologist George Ellis in an article published in *Scientific American* in 2011. "The arguments are indirect at best. And even if the multiverse exists, it leaves the deep mysteries of nature unexplained."

Of course, falsifiability itself has its detractors. Other more widely accepted theories, such as the existence of dark matter or dark energy, may not be falsifiable. Should we also consign those to the scrapheap? It's fair to say that this is a topic that draws heated debate in the scientific community.

And even aside from falsifiability, we run into a problem. Not only can we not disprove multiverse theories, but we can't currently prove them either. We have no way of jumping to another universe, or even observing one. How are we supposed to sift through the myriad of claims being made when there is no direct evidence available?

The idea of a multiverse is undoubtedly an intriguing one. It has inspired a huge range of science fiction, and has garnered support from some of the most prominent physicists today. "It would not be beyond the realms of possibility that somewhere outside of our own universe lies another different universe," Professor Stephen Hawking said in 2015. But it remains divisive, and will do so for the foreseeable future. For now, it remains a fringe theory in some corners. And perhaps in an issue of **How It Works** in an alternate universe, it is indeed confined to the Theology section.

LEVEL THREE: Many worlds

The many-worlds theory relies on quantum mechanics. The quantum world is odd, in that things such as photons can appear to be in two places, or states, at once. It is only when we observe the photon that its state is decided.

In this theory, though, both states exist. And, in fact, this is happening constantly for everything around us, at all times. Each time there is a 'split', a new universe is created, giving rise to an infinite number of universes. This is probably the closest theory to the idea of 'parallel universes' where one could envision jumping into a nearby universe. It's pretty unlikely that'll ever be possible, though.

LEVEL FOUR: Mathematical universe

This theory is probably the one that is most widely derided. Max Tegmark goes into detail in his doorstop of a book *Our Mathematical Universe*, but in essence, it suggests that our universe, and all other universes, are nothing but mathematical constructs. We are quite simply lumps of mathematics manifested as a consciousness that can perceive this seemingly 'real' world.

It is described by some as the 'ultimate ensemble' and, owing to its nature being everything broken down into mathematics, there cannot be another broader multiverse theory beyond it. As you might have guessed, it's a bit controversial.

Arguments for and against the multiverse

FOR

Cosmic inflation
Our universe grew exponentially in the first moments of its existence, but was this expansion uniform? If not, it suggests different regions of space grew at different rates – and may be isolated from one another.

Mathematical constants
How are the laws of our universe so exact? Some propose that this happened only by chance – we are the one universe out of many that happened to get the numbers right.

The observable universe
What is beyond the edge of the observable space around us? No one knows for sure, and until we do (which could be never), the thought that our universe extends infinitely is an interesting one.

AGAINST

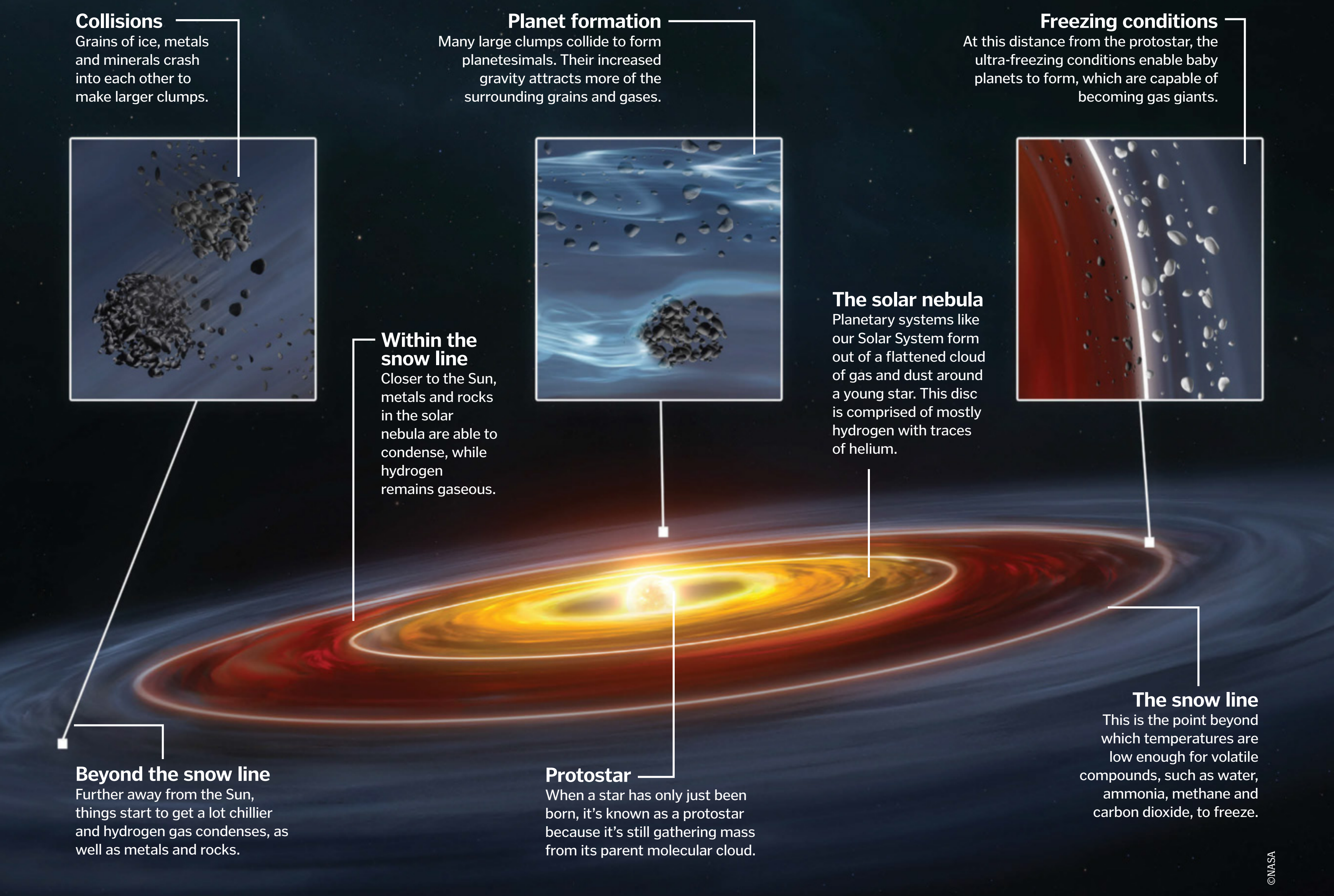
Falsifiability
There is no way for us to ever test theories of the multiverse. We will never see beyond the observable universe, so if there is no way to disprove the theories, should they be given credence?

Occam's razor
Sometimes, the simplest ideas are the best. Some physicists argue that we don't need the multiverse theory at all. It doesn't solve any paradoxes, and only creates new complications.

No evidence
Not only can we not disprove any multiverse theory, we can't prove them either. We currently have no evidence that multiverses exist, and everything we can see suggests there is just one universe – our own.

How frozen worlds form

Icy planets exist beyond the Solar System's snow line



How to wash your hair in space

Microgravity makes hair care on the ISS pretty tricky

If you can't stand the thought of not having a shower for months on end, then look away now. This is one of the prices that astronauts on the International Space Station have to pay for the chance to live in Earth orbit.

If you've ever seen the way water behaves in microgravity, then you can probably imagine that completing a task as simple as giving your roots a good scrub can be difficult. Rather than falling straight down as it does on Earth, water in microgravity scatters into watery blobs. Rogue droplets and hair strands can create safety hazards, so personal hygiene routines become a little more challenging. During her time on the International Space Station back in 2013, astronaut Karen Nyberg demonstrated the elaborate process in a video for viewers back on Earth. First, warm water from a sealed pouch is squirted onto the scalp and quickly caught by a comb that's run through the hair to ensure that no water floats away. A no-rinse shampoo is then rubbed in using a towel, followed by a small amount of water to rinse out any residue. The same towel is used to dry the hair, taking care to catch any loose strands that escape in the process.

A sealed bag of warm water, no-rinse shampoo, a comb and a towel are required to wash your hair in space

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Extraterrestrial skies

Find out what it's like to look up from the surface of another world

On Earth, the position of the Sun relative to our planet makes us the toast of the Solar System. Located in the habitable zone, where the Sun is the right distance to make it neither too hot nor too cold, we are treated to relatively moderate temperatures. We also enjoy a brilliant blue sky, as molecules in our atmosphere scatter more blue light than any other colour.

Take a trip to the planets Venus and Mercury, though, and it's a different story. On the former, the atmosphere is extremely thick, so you'd be hard-pressed to see the Sun (and nor would you on Jupiter, Saturn, Uranus or Neptune), but based on some landers sent there by the Soviet Union in the 1970s and 1980s, we know the sky looks kind of orange-red. On Mercury, which has no atmosphere, the Sun would shine a brilliant – and scorchingly hot – white.

We're not the only planet with a blue sky, though. Jupiter, Saturn, Uranus and Neptune, and maybe even Pluto (we're including it as a 'classical' planet here, although it is a dwarf planet) are also likely to have blue skies, but we don't know for sure because we've never looked up from beneath their atmospheres. On Mars, the sky is usually red, except at sunset and sunrise, when it appears blue.

The distance from the Sun also affects the length of the day on each planet, and how long the Sun hangs in the sky. On Mercury, which rotates the slowest of the planets owing to the Sun's gravitational pull, the time between sunrise and sunset is 88 Earth days. At the other extreme, Jupiter rotates the fastest, with the time between sunrise and sunset being just under five hours on average. Our sky is unique, and looking up from any other world would seem incredibly alien.

***Note:** 1 AU (Astronomical Unit) is the distance from Earth to the Sun

Mercury

On Mercury, the closest planet to the Sun at 0.39 AU*, the Sun would appear about 2.5 times larger than it does on Earth. A day on Mercury lasts 176 Earth days, so it would be in the sky for a long time.

Venus

Venus, at 0.72 AU, is the hottest planet in the Solar System due to its thick atmosphere. You wouldn't see the Sun from the surface, but above the clouds it would appear a third bigger than on Earth.

Earth

Earth is in the prodigal habitable zone of the Solar System, where the distance from the Sun (1 AU) is just right for liquid water to exist. As such, we have a brilliant blue sky dominated by the Sun in the day.

Mars

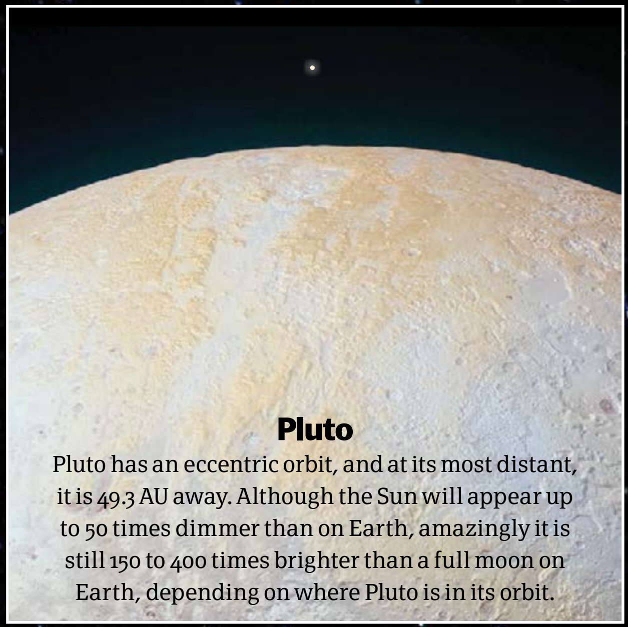
From Mars, 1.5 AU away, the Sun would appear about two thirds smaller than it does on Earth. It receives only 40 per cent of the light Earth does, which makes the Red Planet quite a bit dimmer than our own.

Some exoplanets have more than one bright sun in their sky

Outside the Solar System

To date, we've found thousands of planets outside our Solar System, and some orbit in bizarre systems that would make their skies unlike any of our own planetary neighbours. One system 250 light years away is especially unusual. Known as 1SWASP J093010.78+533859.5, it contains five stars, with two pairs in very tight orbits. Any planets in orbit around any of those stars would put Tatooine from Star Wars to shame.

Another world, Kepler-70b, has one of the closest orbits we know of. It swings around its star in just 5.76 hours at a distance of only 900,000 kilometres or 0.006 AU, less than three times further than that at which the Moon orbits the Earth. Its bright, burning star would easily fill a large portion of the sky. And spare a thought for anyone on 2MASS J2126–8140, which takes a million years to orbit its star. From its distant orbit a trillion kilometres away, you'd be hard-pressed to see the star at all.

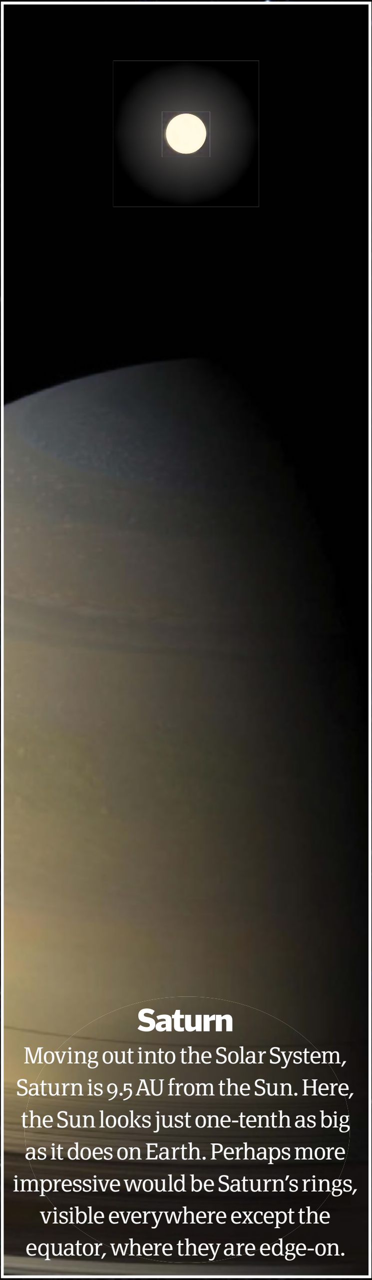


Pluto

Pluto has an eccentric orbit, and at its most distant, it is 49.3 AU away. Although the Sun will appear up to 50 times dimmer than on Earth, amazingly it is still 150 to 400 times brighter than a full moon on Earth, depending on where Pluto is in its orbit.

Jupiter

At 5.2 AU, on Jupiter the Sun is just a quarter of the size it is from Earth, and it is 27 times fainter. But Jupiter has the largest planetary atmosphere in the Solar System, so even if you could survive beneath it, you wouldn't see anything.

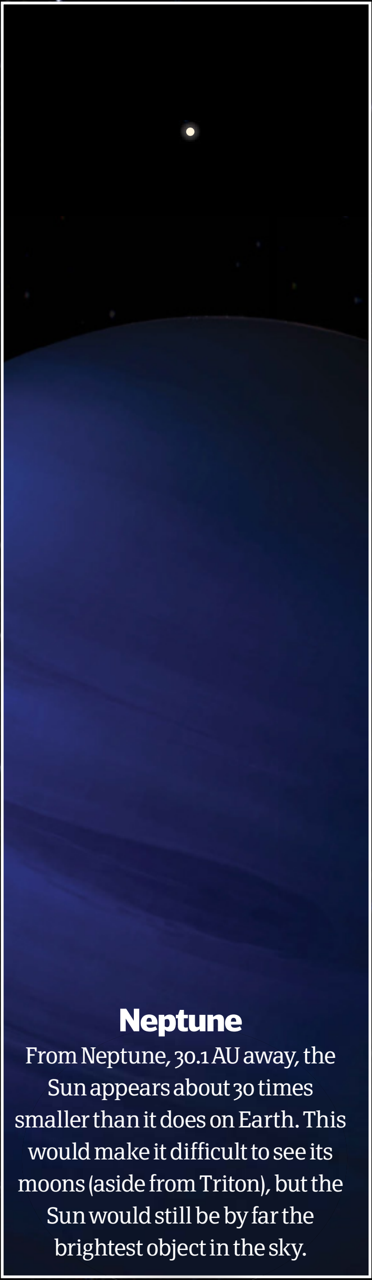


Saturn

Moving out into the Solar System, Saturn is 9.5 AU from the Sun. Here, the Sun looks just one-tenth as big as it does on Earth. Perhaps more impressive would be Saturn's rings, visible everywhere except the equator, where they are edge-on.

Uranus

Now in the outer Solar System, Uranus is 19.2 AU away. From here, the Sun is just one-twentieth the size it is on Earth. As such, it would be difficult to make out the 27 moons of Uranus from the planet, all of which would be quite dim.



Neptune

From Neptune, 30.1 AU away, the Sun appears about 30 times smaller than it does on Earth. This would make it difficult to see its moons (aside from Triton), but the Sun would still be by far the brightest object in the sky.

Animal astronauts

Meet the creatures that paved the way for human spaceflight

Two chimpanzees, Ham (pictured) and Enos, were sent into space during NASA's Mercury Program

1 Fruit flies

On board a captured Nazi V-2 rocket in 1947, these tiny pests made history. They were the first animals in space, sent to explore the effects of radiation on organisms. They returned to Earth safely by parachute.

2 Monkeys

A total of 32 monkeys have flown to space, beginning with Albert II in 1949. A decade later, a rhesus and a squirrel monkey became the first to survive the trip, experiencing over 30 times the pull of Earth's gravity.

3 Mice

Even today, mice are ferried to and from the ISS and are key for studies in sending humans to Mars. Recently, it was discovered that astro-mice sent to deep space showed signs of liver damage.

4 Dogs

During the 1950s and 1960s, dogs were used by the USSR to investigate whether human spaceflight was feasible. The Soviets chose canines believing they could cope with the stress of the experience better than other animals.

5 Geckos

Russian scientists sent lizards to space to study how weightlessness affects reproduction. When one wriggled free of its identification collar, the geckos were filmed playing with the floating object – a rare behaviour for reptiles.

6 Cats

In 1963, the very first feline was sent into space by French scientists. The cat, known as Félicette, had electrodes implanted in her brain in order to record impulses sent back to Earth.

7 Rats

Love them or hate them, we're physiologically similar to rodents. That's why a team of 'ratstronauts' are currently being used to study how microgravity affects organisms during long stays in space.

8 Tortoise

The very first tortoise was launched into space in 1968 with wine flies and mealworms. They flew around the Moon and back to Earth, making them the first animals to enter deep space. What's more, they survived the trip!

9 Cockroaches

Cockroaches conceived on board the International Space Station were found to grow faster, run quicker and were much tougher than those born on Earth. Perhaps it's time to welcome our new insect overlords.

10 Jellyfish

What do humans and jellyfish have in common? We both orientate ourselves according to gravity. NASA raised thousands of the critters in space to test the effects and found the astro-jellies couldn't swim in normal gravity back on Earth.

Laika: the first animal in orbit

Padding through the streets of Moscow, Laika – a mongrel – was plucked from obscurity to stardom. Soviet scientists reasoned that since she was capable of withstanding extreme cold and hunger as a stray dog, she would be able to endure a rigorous training schedule, which would prepare her for a trip to space in 1957.

Before being confined to the capsule – essentially a metal ball weighing around 18 kilograms – Laika's fur was sponged with a weak alcoholic solution and iodine was painted onto the areas where sensors would be placed to monitor her bodily functions.

There were no plans to retrieve Laika from space and she died several hours into the flight from stress and excessive heat – causes that were kept a secret for 40 years. Sputnik 2 circled the Earth 2,570 times before burning up in the Earth's atmosphere. In 2008, a monument was erected in Laika's honour, outside the Moscow facility where she was trained.

Laika was selected for the rigorous astro-training because she had survived tough conditions as a stray

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

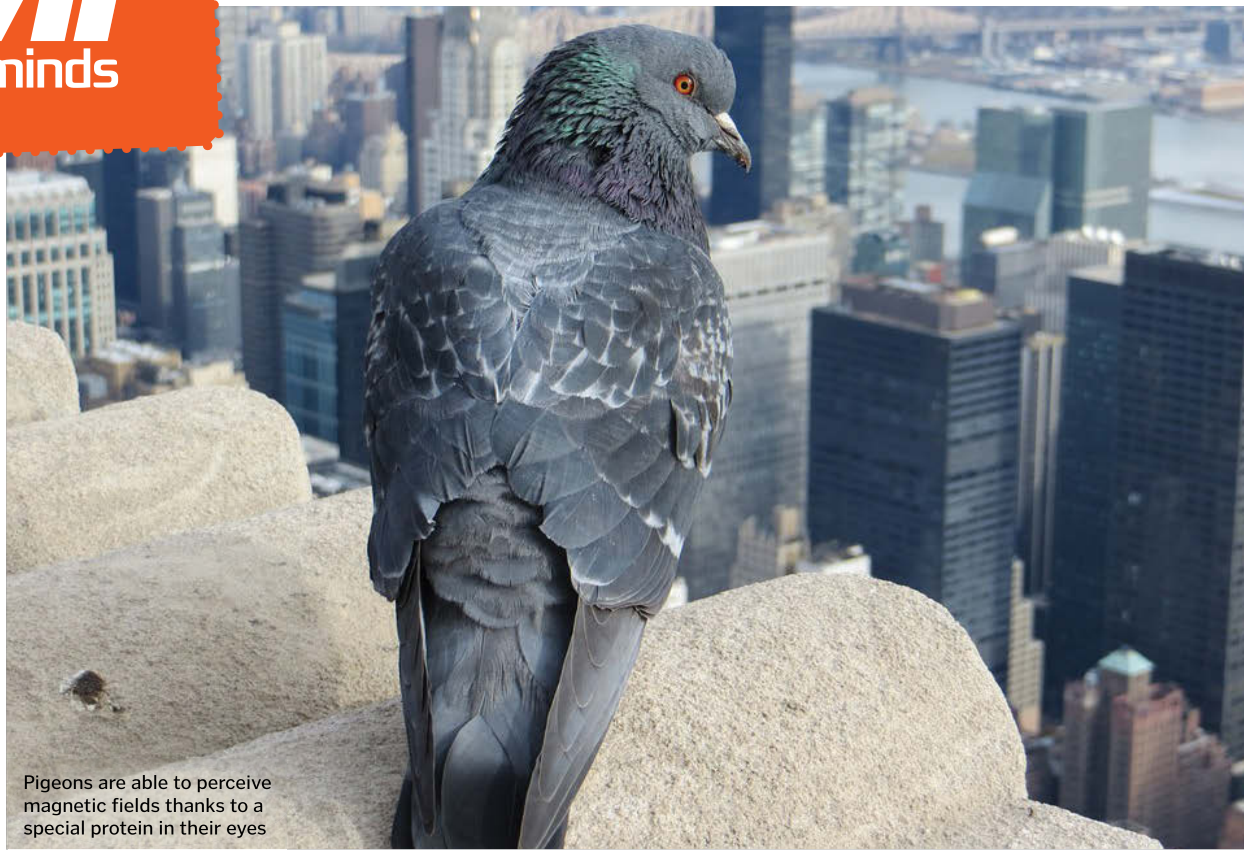
Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds that her job comes in very handy for taking part in quizzes!

Gemma Lavender

Gemma is the Editor of **All About Space**. She holds a master's in astrophysics, is an elected fellow of the Royal Astronomical Society and an associate member of the Institute of Physics. She is a STEM Ambassador and has been a keen observer of the sky for 15 years.



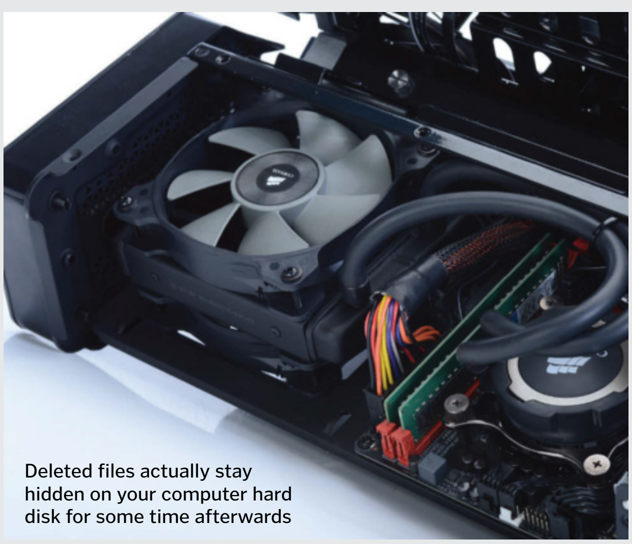
Pigeons are able to perceive magnetic fields thanks to a special protein in their eyes

Can humans sense magnetic fields?

Lauren Woods

There is no conclusive evidence to suggest that humans can perceive magnetic fields. However, many animal species do have this ability, which is known as magnetoreception. The mechanism behind this 'sixth sense' remained a mystery until relatively recently, when researchers found that several species, including pigeons, monarch butterflies and fruit flies, possess proteins called cryptochromes in their eyes. These appear to help them navigate, possibly by 'seeing' magnetic fields as light or dark areas as the proteins align along magnetic field lines.

Humans also have cryptochromes in their retinas. The proteins play a role in regulating our internal body clocks but their presence has led some to speculate that we could possess some vestigial knack for sensing magnetic fields. However, numerous studies have attempted to test our perceptions to magnetic fields, and none have proven that we have any ability to do so. **AC**



Deleted files actually stay hidden on your computer hard disk for some time afterwards

What happens when files and photos are deleted off a computer?

Anthony Millen

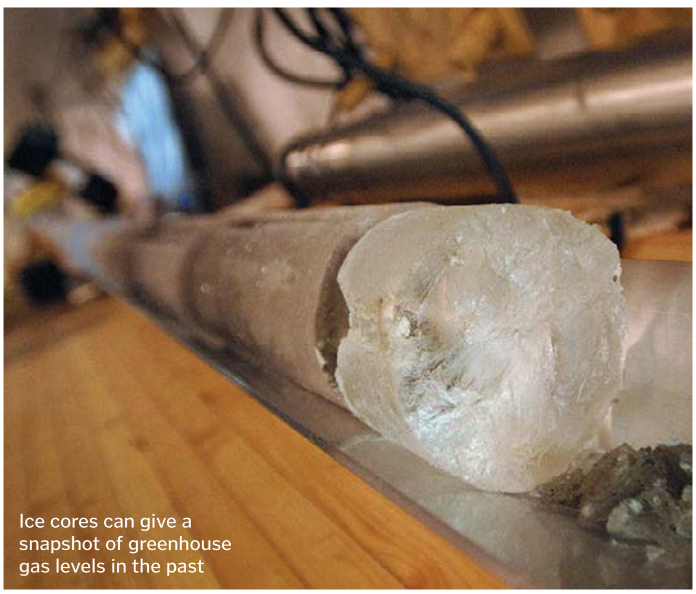
When you delete a file on a computer you probably think it's gone forever, but it's not. Deleting a file just removes the label that tells the computer the file is there. All the data that used to be part of the file will still be there somewhere on your hard disk. It's a bit like taking the cover off a book, but leaving all the pages behind – the book may be gone, but the information is still there. The file only really gets erased when the computer eventually stores something new where the old file used to be on the disk. **TL**

Long-term social bonds are vital for elephant survival

Is it true that elephants never forget?

Will Taggart

■ Elephants do forget, but they have impressive memories. They have the largest brains of any land mammal, and some believe that their intelligence is up there with chimpanzees and dolphins. Elephants live for decades, and travel in family groups led by older females. To be successful, they need to be able to keep track of friends and enemies, and they need to navigate long distances over complicated terrain as the climate changes year after year. African elephants have been known to lead their families to long forgotten watering holes in times of drought, to remember injuries and mistreatment, and to recognise the clothing of people who have done them harm. **LM**



Ice cores can give a snapshot of greenhouse gas levels in the past

How do we measure the amount of greenhouse gases being emitted?

Sarah Corbin

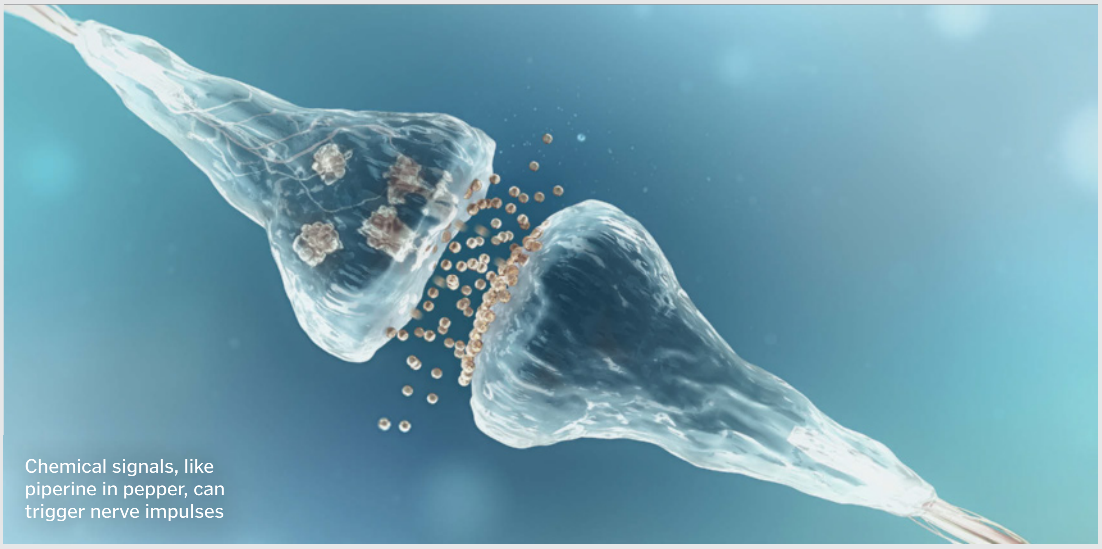
■ Satellites measure greenhouse gases in the atmosphere, while on Earth scientists collect air samples from all over the world. Water vapour and clouds make up the majority of greenhouse gases, with carbon dioxide and other gases comprising about 25 per cent. Current samples are then compared with previous ones, including those from air bubbles that were trapped in ice many thousands of years ago. From this we've determined that the atmosphere contains nearly twice the amount of carbon dioxide (the main greenhouse gas) as there was in 700,000 BCE. With the Industrial Revolution, we began to burn fossil fuels at ever increasing rates, leading to huge jumps in greenhouse gas emissions. In 1750, the atmosphere had a carbon dioxide concentration of about 280 parts per million. By 2000, it was nearly 400 parts per million. **SF**

Who invented Zorbing?

Darren Anderson

■ In 1970s France, an architect called Gilles Ebersolt was probably the first to create a giant inflatable plastic ball for people to get inside and roll around, which he named the 'Ballule'. However, Zorbing as we know it today was created in 1994 in New Zealand by Dwane van der Sluis and Andrew Akers. At the time they were trying to develop inflatable shoes for walking on water. When this failed they came up with the idea for a new fun activity using a giant sphere. They called this the Zorb and then spread Zorbing across the world. **TL**

Zorbs can reach speeds of over 48km/h as they race down hills



Chemical signals, like piperine in pepper, can trigger nerve impulses

Why does pepper make you sneeze?

Jess Johnson

Pepper contains a chemical called piperine, which irritates the sensitive nerve endings inside the nose. Nerve cells are covered in structures called receptors, which detect chemical signals inside the body. Some external chemicals, like piperine, can stick to these receptors and activate the nerves.

One of the receptors that piperine activates is called TRPV1. It is found on nerve cells responsible for detecting burning heat, and is most well known for its interaction with capsaicin (the active chemical found in chilli peppers). The other receptor that interacts with piperine is called TRPA1, which is involved in sensing pain, cold and itch. Triggering either of these receptors might well make you sneeze. **LM**

A little counting and arithmetic can tell you when to get inside to avoid a storm

Can thunder really tell you how far away a storm is?

Alex O'Neill

You can estimate your distance from a lightning strike by counting the seconds between the time you see a flash of lightning and the time you hear the thunder. Take the number of seconds and divide by three. If you count to six, for example, that means the storm is around two kilometres away.

This method is called flash-to-bang. It's based on the fact that sound travels at about 0.3 kilometres per second depending on air temperature, while light travels much faster at about 300,000 kilometres per second. If you calculate that the storm is less than nine kilometres away, it's time to take cover. **SF**

FASCINATING FACTS

What's the maximum speed that a lift can travel?

The world's fastest lifts travel at 18 metres per second. New elevators in China's CTF Finance Centre will smash this record later this year, reaching 20 metres per second. **AC**

Shanghai Tower is currently home to one of the world's fastest lifts

What was the first ever tweet?

At first Twitter was called Twttr. The first ever tweet, or twt, was "just setting up my twttr" sent by its co-creator, Jack Dorsey, on 21 March 2006. **TL**

The original Twttr page looked very different to the Twitter millions of us use today

Why do we say 'cheers' before drinking?

Different cultures have different drinking rituals, but the British 'cheers' is thought to be a way to wish others health and happiness, or 'good cheer'. **LM**

The idea of raising a toast is thought to have originated in ancient Greece or Rome

Clouds are made up of water droplets so small that they barely experience gravity

How do clouds float?

Sam Griffiths

The tiny droplets and ice crystals that make up clouds are incredibly small and light, meaning that gravity has very little effect on them. For something to fall to the ground, the Earth's gravitational pull must be greater than the resistance an object encounters as it moves through the air. Just like particles of dust that float in the air, the droplets' surface area is great enough relative to their mass to keep them afloat. When tiny droplets within a cloud collide, they merge to form larger drops, which eventually fall to the ground as rain. **AC**

How is paint made?

Connie Starkey

Paints vary depending on their use, but all types include three basic ingredients: a binder, a pigment and a solvent. The pigment will usually start off as a lump of rock, so it is first ground into a fine powder. It is then mixed with a binder, which coats the pigment, and a solvent, which thins the paint and makes it easier to apply.

Various additives may also be included in the mixture, depending on what the paint will be used for. For instance, paint for outdoor use contains silicones to make it more weather-resistant, and fine granules can be added to floor paint to make it less slippery. **SF**

Pigment powders are used to make colourful paints

Why do turkeys have both white and dark meat?

Mark Lambert

Muscle fibres come in two major types – fast-twitch and slow-twitch. Fast-twitch fibres are geared for bursts of energy (turkeys use their breast and wing muscles to escape predators), while slow-twitch fibres are adapted for sustained use (leg and thigh muscles are used constantly for standing and walking). The colour of meat is related to which type of muscle fibre it contains. Slow-twitch fibres need a steady supply of oxygen, so they are packed with a protein called myoglobin. This binds tightly to oxygen and provides a ready-made store of it for the muscle. Myoglobin is a deep red colour so this meat appears dark. Fast-twitch fibres contain very little myoglobin, so the meat appears paler. **LM**

Turkeys spend a lot of time standing, but they rarely try to fly

Automatic flush toilets are triggered by sensors that detect your body heat

How do auto-flush toilets work?

Lloyd Granger

With an automatic toilet, you'll probably spot a small black circle nearby that looks a bit like a button – it's an infra-red sensor. This detects body heat, and is connected to an electronic valve inside the water tank. The sensor is triggered when you wave your hand in front of it or move away from the toilet, and sends a signal to the valve to empty the water from the tank. This flushes the toilet and the tank is then refilled. Electric toilets could be hazardous if the water and electricity mixed, so most are battery powered for safety. **TL**

Why does shampoo make more bubbles in your hair than on your body?

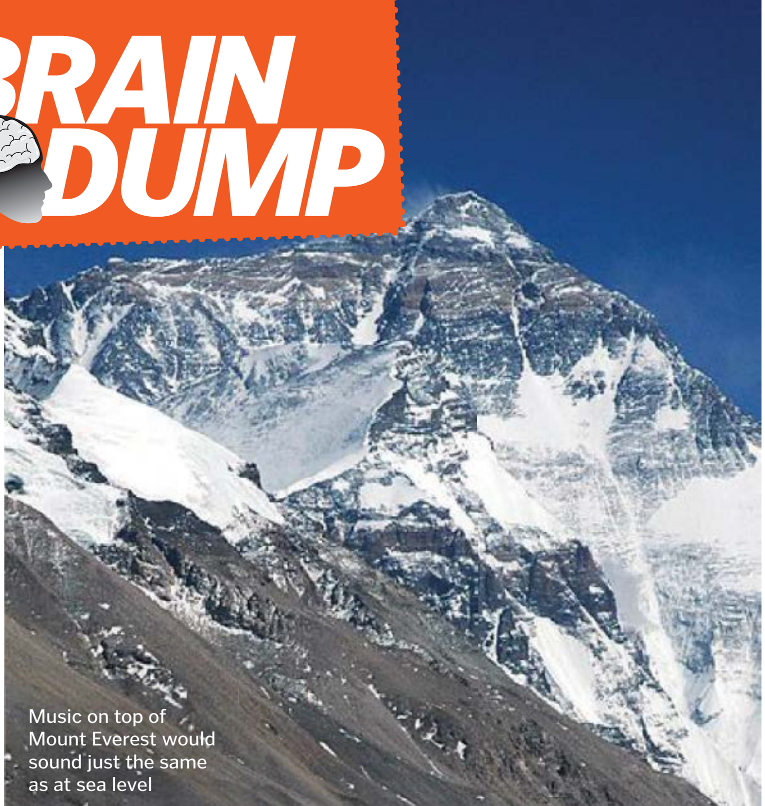
Gabriel Jones

Shampoo makes bubbles because it contains chemicals called surfactants. These are molecules that are part hydrophobic (water-hating), and part hydrophilic (water-loving). They help to pull oils from your hair because the water-loving ends all try to point towards the water, while the water-hating ends want to point towards the oils. This suspends tiny drops of oil in the water, which you then wash out along with the shampoo.

However, surfactants have a second property that helps bubbles to form: they lower the surface tension of water. As you rub the shampoo in, water forms a film between strands, and then curves around the air to make a bubble. Your hair acts like a big collection of bubble wands to create lots of tiny bubbles, or foam. **LM**

Hair acts like a bubble wand, trapping air inside the soap

BRAIN DUMP

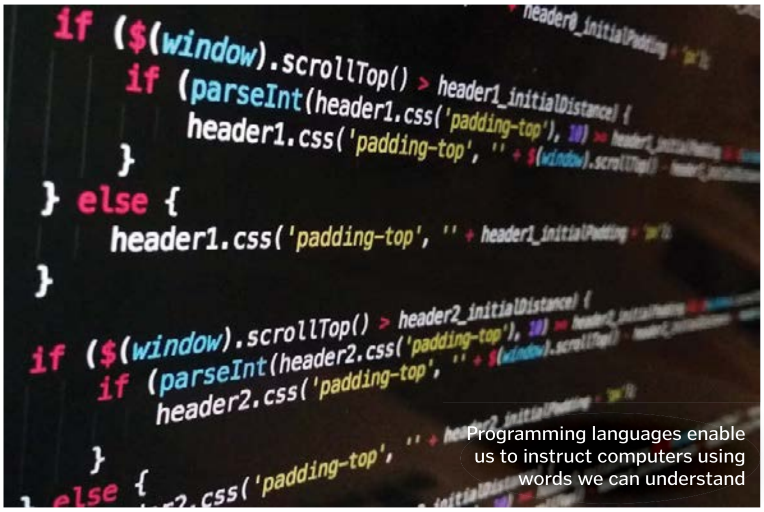


Music on top of Mount Everest would sound just the same as at sea level

Does music sound any different at high altitudes?

Graham Sheen

Although atmospheric pressure and density influence the speed of sound, the two effects essentially cancel each other out. In fact, the most noticeable factor affecting the speed of sound at high altitude is temperature. At colder temperatures, the molecules in the air carry less kinetic energy, making sound waves travel more slowly. At -1 degrees Celsius for instance, sound travels at 330 metres per second, compared to 344 metres per second at 21 degrees Celsius. However, the affect this has on the frequency of sound waves – and therefore their pitch – is so small that music would not sound any different. **AC**



Programming languages enable us to instruct computers using words we can understand

How is a programming language created?

Zubair Beg

Deep down, computer hardware can only understand very basic commands written in machine code. As machine code is basically just ones and zeros, it's difficult for people to understand. Programming languages allow us to instruct computers using concepts and words more like human language, like LOAD and DO, and convert these to machine code that the computer can understand. To create a programming language you first need to define its words and rules.

You then need to work out how instructions in your language relate to instructions in machine code, a bit like translating to a foreign language. Next, you need to create a program called a compiler or an interpreter, which turns programs written in your language into machine code for the computer. It's a complicated process, and new programming languages are often written using existing languages to try to make it easier. **TL**

Cats have about 19 different variations of 'meow'

Why do cats only meow at humans?

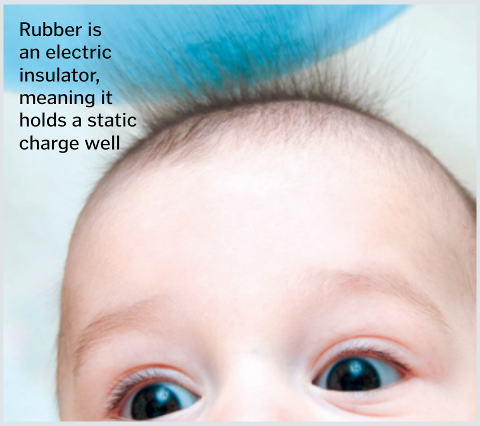
Ellie Cole

Cats only meow at each other as kittens; adult cats only meow at humans. That's because they've learned that we respond to it. Cats meow when they're hungry, need to go out, want your attention, or just want to say hello. Older cats or cats with mental disorders may also meow for no apparent reason. In general, though, they're meowing to let you know something, even if you can't always figure it out. Cats do yowl at each other – a long, extended form of meow – during mating or fighting. **SF**

Why do balloons hold so much static?

Elsa Jenkins

Balloons retain a static electric charge due to the insulating properties of rubber. This material has a high electron affinity (likelihood of gaining electrons) relative to hair, so when you rub a balloon against your head, electrons easily come off your hair and build up on the surface of the balloon, and it acquires a negative static charge. Rubber is an electrical insulator, meaning that electrons cannot move through it easily. The air around the balloons is also an insulator, so the negative charge remains on the balloon's surface. However, if you touch the balloon with an electrical conductor, such as a metal ruler, the charge rapidly dissipates. **AC**



Rubber is an electric insulator, meaning it holds a static charge well

FASCINATING FACTS

What is the oldest object ever found?

Taylor Young

The oldest man-made objects found so far are stone tools that predate humans, used about 3.3 million years ago in Kenya. The oldest fragment of Earth's crust we've found so far is a 4.4-billion-year-old zircon crystal. **SF**

Zircon crystals found in Australia date back to 4.4 billion years ago

ASK THE ASTROPHYSICIST

Astronomy top tip
Invest in a star chart and binoculars to familiarise yourself with the night sky

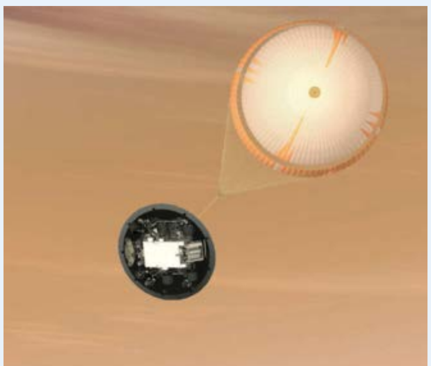
Gemma Lavender
Gemma is the Editor of **All About Space.**

What would happen if you used a laser pointer in space?

Max Cripps

Because photons of light carry momentum, a laser pointer floating in space would very gradually find itself pushed backwards in reaction to the beam of photons that are leaving the laser in the opposite direction – remember Newton's Second Law, which says that every action has an equal and opposite reaction. But you couldn't shine a laser pointer at, say, Pluto from Earth and expect to see a red dot on Pluto's surface. This is because laser beams disperse – if you shine a laser pointer at a wall you can see the spot is wider than the beam leaving the laser.

Laser beams fired in space will gradually disperse as they travel



Spacecraft landing on Mars can parachute down to the ground

What makes landing on Mars different to the Moon landing?

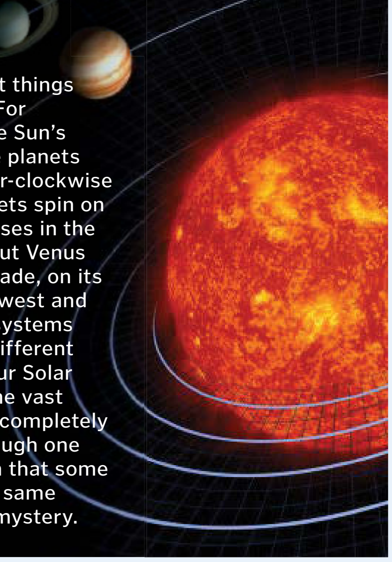
Carla Martinez

There are three things that make landing on Mars different from landing on the Moon. The first is gravity – the acceleration due to gravity on Mars is 3.7 metres per second squared, while on the Moon it is 1.6 metres per second squared, so Mars' gravity pulls a spacecraft down faster. The second difference is that Mars has an atmosphere, whereas the Moon is airless. A spacecraft landing on Mars can use parachutes to slow its descent, but these wouldn't work on the Moon. Entry into Mars' atmosphere also generates heat through friction, so Martian spacecraft need heat shields. The third difference is the distance between Earth and the Moon, which on average is 384,000 kilometres, and the distance between Earth and Mars, which ranges from 55 million kilometres to 400 million kilometres. This affects the time it takes for signals to reach the spacecraft from Earth. On the Moon, a spacecraft can be controlled in practically real time, but on Mars the time delay means a spacecraft has to be capable of landing by itself without assistance from Earth.

Does everything in space spin in the same direction?

Gareth Poynter

In our Solar System, most things spin in the same direction. For example, an observer on the Sun's north pole would see all the planets orbiting the Sun in a counter-clockwise fashion. Most of those planets spin on their axes so that the Sun rises in the east and sets in the west, but Venus spins backwards, or retrograde, on its axis so the Sun rises in the west and sets in the east. Planetary systems around other stars spin in different orientations compared to our Solar System. On larger scales, the vast majority of galaxies spin in completely different orientations, although one recent discovery has shown that some galaxies are spinning in the same directions. The reason is a mystery.



The planets in our Solar System all orbit the Sun in the same direction

What was the first planet to be discovered?

Kia Woodhead

Mercury, Venus, Mars, Jupiter and Saturn are all visible to the naked eye, so it is impossible to say who first spotted them, or when. The first planet to be discovered with a telescope was Uranus, by Sir William Herschel in 1781.

Uranus was the first planet to be knowingly discovered

The ISS has thermal control systems to keep its temperature balanced

Is there air conditioning on the ISS?

Charlie Allen

The International Space Station (ISS) does feature air con, in the sense that it has a system for removing heat and cooling the air that the crew on board breathe. When in direct sunlight, the ISS can become as hot as 90 degrees Celsius, so the inside needs to be kept cool. There are air and water heat exchangers, as well as a system of cold pipes that circulate ammonia through the station. Ammonia is a thermal conductor, which means it can remove heat from inside the crew compartments and radiate that heat back out into space.

What's happening on... Twitter?

Join **All About Space** every Saturday 6-9pm (GMT/BST) for a Q&A on Twitter where your astronomy questions will be answered live! Tweet your questions to **@spaceanswers** and follow **#StargazerSat**

@Oh4amuseoffire
@spaceanswers Is **@MarsCuriosity** able to witness an eclipse from Mars?

Only eclipses made by its own moons. Mars' moons are relatively small, so Curiosity will only see a partial eclipse.

@milyellex
@spaceanswers When is the next visible meteor shower?

The next is the Delta Aquarids on 27 July. After that, the Perseids are visible in August.

@par4er_y
@spaceanswers Why is space darker in the background than in the foreground?

Space actually has the same darkness everywhere – unless you happen to be near a star or light-reflecting planet!

@pilliarscreatio
@spaceanswers What is a double delta wing on a Space Shuttle?

These are triangular wings that helped the Shuttle achieve efficient flight at hypersonic speeds, and gave it a good lift-to-drag ratio for a slow landing.

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BOOK REVIEWS

The latest releases for curious minds

Forgotten Science: Strange Ideas From The Scrapheap Of History

Think science is all about logic and reason? Think again

- Author: **S D Tucker**
- Publisher: **Amberley**
- Price: **£18.99 / $29.95**
- Release date: **Out now**

In modern times science has stood at the forefront of human achievement. No major breakthrough from the 21st century would have been possible without countless experiments and strenuous trial and error. Vaccinations, surgical procedures and anatomy are things we usually take for granted nowadays and we rarely give much thought to their origins or evolution. These are the kind of topics that S D Tucker tackles in his book *Forgotten Science*. Here he has combed the funniest, wackiest and most depraved scientific experiments and theories from throughout history such as pet reanimation, the secrets of human evolution and farting cows.

Tucker does a particularly good job of telling an experiment's story through both contemporary and modern perspectives. While some experiments, like trying to cure tuberculosis by having patients inhale a cow's gassy emissions, might seem ludicrous by today's standards, they were somewhat accepted theories in the late 18th century. The author is able to explain the processes and thinking behind the madness, and while poking fun at many of the experiments, remains true to the facts.

Although there are only a few laugh-out-loud moments, the stories will have you smiling to yourself throughout. The light-hearted and playful tone is constant through the book, which could lead some to believe that the subject matter is not worthy of thought. However, the author is constantly challenging the reader to examine each harebrained scheme they're introduced to, and to consider the moral implications of such research. Do the results of these experiments justify the sometimes cruel and horrific means? Questions like these help *Forgotten Science* become more than just a list of zany theories and crackpot experiments. Tucker seems to address the moral dilemmas of science rather than the hard facts, and while he backs up his work with references, the more hardcore science fans will be left wanting more and answers from the experiments told within.

YOU MAY ALSO LIKE...

Great British Eccentrics

Author: **S D Tucker**
Publisher: **Amberley**
Price: **£16.99 / $17.95**
Release date: **Out now**

In much the same tone as *Forgotten Science*, Tucker relishes in telling the stories of mad and entertaining subjects, and giving accounts of the best oddball characters from British history.

The Invention Of Nature

Author: **Andrea Wulf**
Publisher: **John Murray**
Price: **£9.99 / $16.95**
Release date: **Out now**

Andrea Wulf gives us an insight into the extraordinary life of naturalist Alexander von Humboldt, whose achievements are too often forgotten in the modern world.

The Evolution of Everything

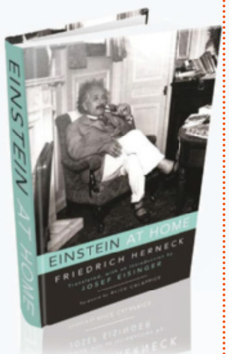
Author: **Matt Ridley**
Publisher: **HarperCollins**
Price: **£9.99 / $16.99**
Release date: **Out now**

Another title that will make you think about how the world works, Matt Ridley has written a compelling book on the driving forces behind human achievement and growth.

Einstein At Home

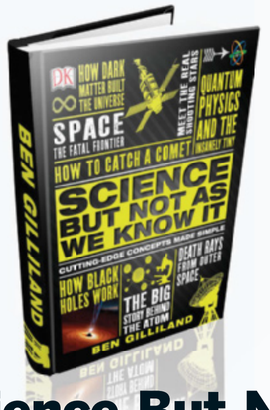
A behind-the-scenes look at one of history's greatest minds

- Author: **Friedrich Herneck**
- Publisher: **Prometheus Books**
- Price: **£14.99 / $18**
- Release date: **Out now**



In the modern world of reality TV, it is totally normal to take a look into the private life of a celebrity, but in the middle of the 20th century this concept was incredibly rare. However, thanks to a series of interviews from the 1970s with Einstein's live-in housekeeper, Herta Waldow, Herneck managed to extract insider information that otherwise would have been lost to history. This book translates those interviews into English for the first time. Surprisingly, it's the mundane parts of the book that kept us hooked, like stories about the parakeet kept by Einstein's stepdaughter, or the fact his short-sighted wife was the one who cut his constantly unkempt hair.

★★★★★



Science But Not As We Know It

Simplifying complicated concepts, from quantum physics to dark matter

- Author: **Ben Gilliland**
- Publisher: **Dorling Kindersley**
- Price: **£9.99 (approx $14)**
- Release date: **Out now**

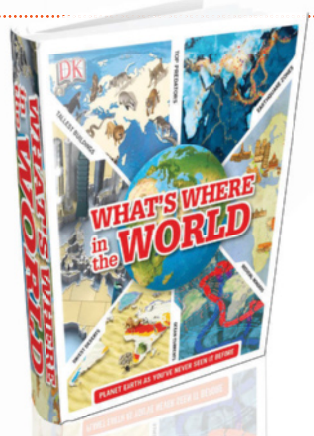
We love big questions, and Gilliland certainly isn't afraid to ask them. Questions like, "Are we just one bubble of existence in an infinite multiverse?" and "What is dark matter?" are peppered throughout this book. That does mean that the science within these pages *can* get fairly advanced (you'll be learning about string theory in here, too) but it's dealt with intelligently. It's well organised, well written and covers dozens of concepts and ideas – you'll just need to make sure your brain is fully switched on as you read.

★★★★☆

What's Where In The World

An old-school atlas with a modern twist

- Author: **Rob Houston**
- Publisher: **Dorling Kindersley**
- Price: **£12.99 (approx $19)**
- Release date: **Out now**



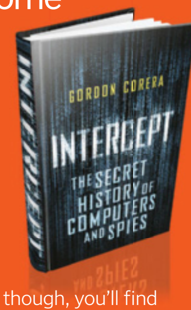
It might seem like a strange idea to buy a book like this when you want to learn facts about the world – after all, in 2016 everything is available on the internet, right? That may be true, but this book is so brilliantly and simply presented that it is well worth a look. Each double-page spread shows a map with a new topic displayed across it. Whether it's the distribution of air traffic across the world, or the number of billionaires in each country, these maps present fantastic data in an interesting and engaging way. You get facts about nature, history, technology, culture and more packed into this one volume – we found ourselves stopping regularly and telling anyone nearby the best facts as we read.

★★★★★

Intercept: The Secret History Of Computers And Spies

Time to start thinking of some more secure passwords

- Author: **Gordon Corera**
- Publisher: **Orion Books**
- Price: **£8.99 / $29.95**
- Release date: **Out now**



With security and privacy constantly at the centre of modern discussions, and governments regularly developing new powers to observe their people, you'd be forgiven for thinking that this book was simply pandering to scaremongers. In reality, though, you'll find that it presents both sides of the modern-day security argument, then settles back and allows you to decide for yourself what to think. By the end, though, our minds were *less* made up, our passwords were far stronger and we'd stuck tape over the webcam on our computers.

★★★★★

Build Your Own Drone

...but only if you really know what you're doing

- Author: **Alex Elliott**
- Publisher: **Haynes Publishing**
- Price: **£22.99 (approx $33)**
- Release date: **Out now**

Whether you're piloting a tiny, four-rotor machine around your kitchen and crashing into potted plants, or watching footage shot in amazing 4K by a powerful quadcopter, drones have allowed us to do a lot that we couldn't before. And if you want to build your own drone, now you can using this handy guide. Be warned, though – you *really* need to know what you're doing.

Of course, this has always been the case with Haynes guides, but you'll need a lot of equipment and some specialist knowledge before you have a go at creating a quadcopter. This is great for those after a serious project, but if you just want to fly we'd recommend investing in a ready-assembled drone.

★★★★½

On The Space Station

A children's book for the 21st century

- Author: **Carron Brown & Bee Johnson**
- Publisher: **Ivy Press**
- Price: **£10.99 (approx $16)**
- Release date: **Out now**

Children's books no longer have to be about farm animals and imaginary aliens. This informative (but highly entertaining) read explains in simple terms what happens when astronauts climb into a rocket and blast into space to work on the International Space Station. The twist here is that every other page is black with white ink illustrations; hold this page up with a light behind it and the white ink shows through onto the page before, adding hidden details to the images and progressing the story. Turn the page and these extra details are explained.

★★★★★

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Skills for surviving the modern world

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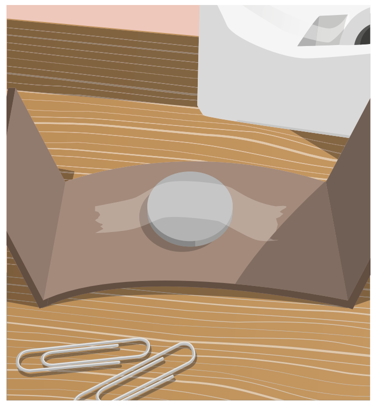
Make a speaker

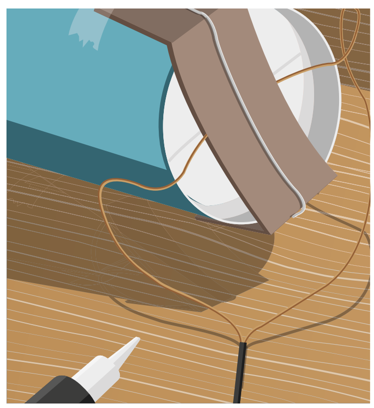
Boost the sound from your phone or computer, and learn more about magnetism with this cool project

1 Coil the wire
To begin making your speaker, take a circular magnet and wrap some copper wire around it six or seven times. You will need at least 10 centimetres of wire left at each end. Slide the coil off the magnet and tape it to the bottom of a large paper cup, with one end of the wire trailing over each edge of the cup. This will soon become an electromagnet!



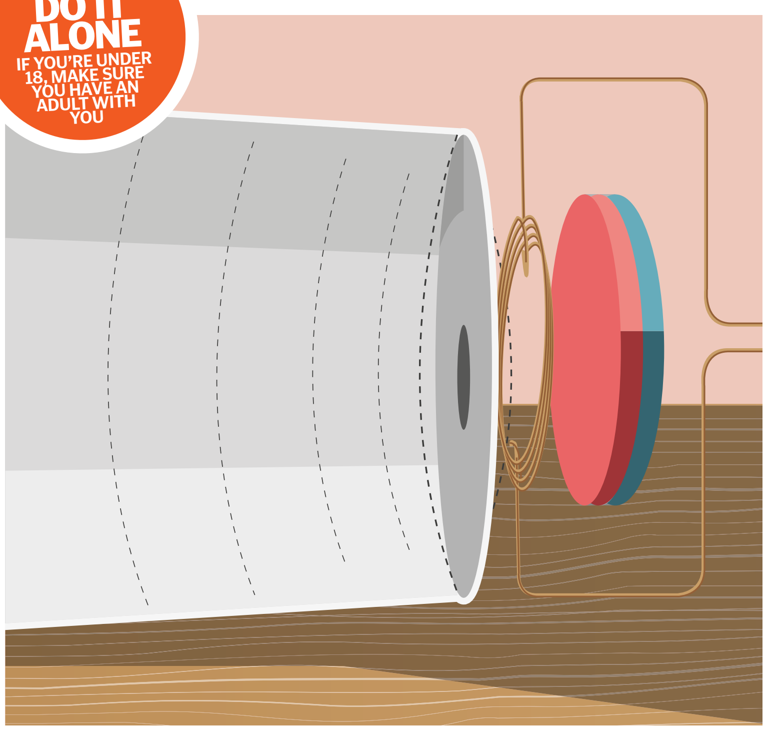
2 Secure the magnet
Next, take the magnet and tape it to one side of a firm piece of cardboard. Make the cardboard stronger by straightening out a paperclip and taping it securely to the other side. Fold both ends of the cardboard so the whole piece sits neatly on the bottom of the cup – you should end up with a U-shaped piece with the magnet on the inside of the U.

3 Attach and secure
Tape the cardboard to the cup as securely as possible. You don't want the magnet to move when the music is playing, as it will lessen the effect of the speaker – the speaker will push an electric current through the wire coil, making it magnetic. This will make it move (and the bottom of the cup) to create vibrations in the air. These are sound waves!



4 Solder it
You now need an audio jack so you can connect the speaker to your device. There will be two wires inside the jack's cable, and you need to ask an adult to help you use a soldering iron to attach these to the two copper wires you left trailing over the edge of the cup. It doesn't matter which way they are connected, as long as they are attached.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



5 Pump it up!
You can create a cardboard case for the speaker if you wish, but it should work perfectly well without. When you play your music, the copper wire becomes an electromagnet that attracts and repels from the second magnet. This makes the base of the cup vibrate, and it creates sound waves, which bounce off the inside of the cup and become amplified. The quality won't be able to match shop-bought speakers, but this is a great way of understanding how the technology works.

In summary…
The key here is magnetism; the wire coil becomes an electromagnet when a current flows through it. This causes it to rapidly change between being positively charged and negatively charged, so it is attracted and repelled by the magnet over and over again, creating vibrations. This is how every speaker works on a basic level, making it surprisingly easy to recreate at home.

NEXT ISSUE
- Water wheels
- Make fizzy sherbet

Conjure a cloud

Create a jar overflowing with water vapour using everyday household objects

Illustrations by Edward Crooks

1 Boil some water

First, boil some water in a kettle. Water vapour is what the clouds in the sky are made of, and when water boils it creates this vapour in small quantities – which is the steam you see coming out of the kettle. However, we want to try and form this vapour into much denser clouds, so pour your boiling water into a large jar when it is still hot. Be careful and ask an adult for help if you need to.

2 Add hairspray

Next, you will need something to help the steam form into larger droplets. Take a can of aerosol hairspray and spray it into the jar. The hairspray is made up of lots of tiny particles, and as the boiling liquid creates water vapour, the hairspray gives the vapour a surface to condense onto. This will create lots of tiny droplets that will start to look like a cloud that you might see in the sky, only on a smaller scale.

3 Close, ice and enjoy!

To maximise the effect, close the jar and place a few ice cubes on the lid. This will dramatically cool the air inside the jar and make the water vapour condense even faster, so the jar will quickly fill up with cloud. In next to no time you won't even be able to see through the jar! Even so, be patient and wait until the jar is really full before you open the lid. Then you can sit back and enjoy watching the cloud 'leak' out of the top of the jar.

In summary...

Clouds form when water vapour has a surface to condense onto. In the sky, tiny flecks of dust floating in the air are enough for the water to attach to, which is what forms the clouds we see. The hairspray here acts like that dust, and the ice cools the air to make condensing even faster.

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WIN! AMAZING PRIZE FOR LETTER OF THE MONTH! BUILD YOUR OWN DRONE Drone expert Alex Elliott has created the ultimate guide to building and flying your own Unmanned Aerial Vehicle.

Letter of the Month
Space suited

Dear **HIW,**
When the first space suit was completed in 1961, how did the designers know that it would be suitable before they had even tested it in space?
Isobelle-Hepsy Jones (aged 12)

Before Russian cosmonaut Yuri Gagarin blasted off on the first human space flight in 1961, his SK-1 space suit had been thoroughly tested on Earth by its designers. They checked its strength and how it withstood different temperatures, they spun it at high speeds in a centrifuge, shook it on a shaker, and used it underwater. It was even tested inside a vacuum chamber, a sealed room with all the air sucked out of it, much like conditions in outer space. Finally in 1961, before Gagarin's flight, a life-like mannequin named Ivan Ivanovich was dressed in a space suit and launched into space on two test flights. Ivanovich was fitted with scientific instruments and the data these recorded proved the space suit would be suitable for humans as well as dummies. However, early spacesuits were by no means perfect. In 1965, Soviet cosmonaut Alexei Leonov conducted the first spacewalk. This historic moment nearly ended in disaster after his suit inflated in the vacuum of space.


Yuri Gagarin's space suit was rigorously tested, including this dummy run

What's happening on... Twitter?

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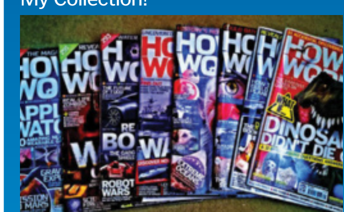
@rh_kes
@HowItWorksmag So I just wasted 5 mins of my life looking at how pasta is made. Aaaamaaazing

@tgordonmallory
My Collection!



@BauzLeBaus
@HowItWorksmag I LOVE the latest mag, can't wait to prove to a select few people that blood ain't blue

@GriffoJack
I liked a @YouTube video from **@Howitworksmag** – Why don't penguins' feet freeze?

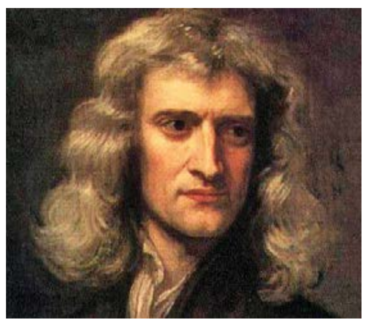
@Sotleyshev68
@HowItWorksmag Can we have a month devoted to environmental tech: solar plane, geothermal etc?

@TomDaley1994
Very happy to confirm my spot on @TeamGB this summer! #GoingToRio

Measuring Earth

Dear **HIW,**
I have really enjoyed reading **How It Works**, especially about physics. I was wondering, is it possible to measure the Earth's mass using its gravity?
Anthony Panke

If we drop a ball with a mass of one kilogram on Earth and measure its acceleration, we can calculate the attractive force, Earth's gravity, using Newton's Second Law of Motion. We can then work out the mass of Earth using Newton's Universal Law of Gravitation, which tells us that the attractive force between the Earth and the ball is directly proportional to their masses multiplied together. If you put the numbers into Newton's equation, it turns out the Earth's mass is 5.9 sextillion tons.


Isaac Newton developed the laws that allow us to calculate the mass of the Earth

Hair vitamins

Dear **HIW,**
I really love your magazine! Please can you tell me if taking high doses of vitamin supplements such as biotin, sea kelp and zinc will help hair growth and or increase its thickness?
Sarah Corbin

Although there are many products available and many claims about their effectiveness, there doesn't seem to be conclusive evidence that vitamin supplements can boost hair growth or increase its thickness. Occasionally hair loss is caused by nutritional deficiencies – such as in iron or vitamin D – that might be counteracted by the supplements. However, hair loss can also be genetic, and in these cases the supplements are unlikely to have any effect.


There is little evidence that vitamin supplements can improve hair growth


Holding your breath is one of many methods thought to stop hiccups

Hiccups explained

Dear **HIW,**
Your magazine is fantastic. The question I would like to ask is, why do we hiccup?
Will Haynes (aged 11)

Hiccups happen when your diaphragm, a thin layer of muscle between your stomach and your lungs, suddenly tightens with a jerk. The jerk makes you suck in air, and when this air hits the vocal cords in your voice box, the glottis suddenly closes, making the 'hic' sound. Scientists are still unsure why they happen at all. One theory suggests that we have inherited hiccups from our ancient amphibian ancestors that used gills to breathe, which involved contracting the diaphragm and closing the glottis.

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